UNITED STATES DISTRICT COURT

FOR THE DISTRICT OF CONNECTICUT

UNITED STATES OF AMERICA, et al, Plaintiff, v. SOLVENTS RECOVERY SERVICE OF NEW ENGLAND, INC., Defendant.	Civil Action No. H-79-704 (JAC)

CERTIFICATION OF JOHN H. GUSWA

I, John H. Guswa, certify as follows:

1. I am a Vice President and Principal Hydrogeologist of GeoTrans, Inc. ("GeoTrans"). GeoTrans is a consulting firm with expertise in the analysis of, and solutions to, groundwater-related problems. At the request of Solvents Recovery Service of New England, Inc. ("SRSNE"), I reviewed the Declaration of Matthew Hoagland filed by plaintiff, United States of America, in this matter. I have also reviewed additional reports, data and documents regarding the on-site

and off-site groundwater recovery systems installed at the SRSNE facility in Lazy Lane, Southington, Connecticut.

2. My report and evaluation based on my review of the Hoagland Declaration and other documents provided by SRSNE is attached hereto as Exhibit 1.

I certify under penalty of perjury that the foregoing is true and correct.

John H Guswa

John H. Guswa

Dated: September 27, 1990

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Prepared for:

Lowenstein, Sandler, Kohl, Fisher & Boylan

EVALUATION OF THE PAST PERFORMANCE OF THE ON-SITE RECOVERY SYSTEM AT THE SOLVENTS RECOVERY SERVICE OF NEW ENGLAND, INC. FACILITY IN SOUTHINGTON, CONNECTICUT

September 1990

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EVALUATION OF THE PAST PERFORMANCE OF THE ON-SITE RECOVERY SYSTEM AT THE SOLVENTS RECOVERY SERVICE OF NEW ENGLAND, INC. FACILITY IN SOUTHINGTON, CONNECTICUT

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INTRODUCTION

At the request of Solvents Recovery Service of New England, Inc. ("SRSNE"), I have reviewed reports, data, and documents regarding remedial actions to be taken at the SRSNE facility in the Town of Southington, Connecticut. My review has focused primarily on information regarding the on-site groundwater recovery system ("on-site system"), but has also included information regarding the off-site groundwater recovery system ("off-site system"). The purpose of my review was to evaluate the past performance of the on-site system and the appropriateness of the system performance criteria contained in the Declaration of Matthew Hoagland ("Hoagland Declaration").

I am a Vice-President and Principal Hydrogeologist of GeoTrans, Inc. ("GeoTrans"). GeoTrans is a consulting firm with expertise in the analysis of and solutions to groundwater-related problems. GeoTrans has four regional offices in the United States, located in Virginia, Kentucky, Colorado, and Massachusetts. I have been employed by GeoTrans since June 1, 1985 as a hydrogeologist and have managed our Massachusetts office since that time. At the present time, the GeoTrans Massachusetts office employs seven hydrogeologists and geotechnical engineers. Nationally, GeoTrans has more than forty technical employees with expertise in geology, groundwater hydrology, chemistry, geophysics, environmental regulations, and groundwater remediation.

I received a Ph.D. in geology with an emphasis in hydrogeology from Pennsylvania State University in 1976. From 1974 until 1981, I was employed by the Water Resources Division of the U.S. Geological Survey directing projects related to ground and surface water resources. Subsequently, I have been employed as a hydrogeologic consultant by Arthur D. Little, Inc. (1981-1984), Roy F. Weston (1984-1985), and GeoTrans (1985-present). I have extensive experience in field investigations of groundwater hydrology and the application of analytical and numerical models to simulate aquifer systems. I have been responsible for planning and directing programs for regional and local groundwater resource evaluation; supervision of deep and shallow test-well drilling and sampling programs;

design and supervision of aquifer testing, monitoring and analysis programs; development and application of groundwater flow, energy, and chemical transport models; identification of contaminant plumes; and assessment of groundwater contamination and remedial actions. My resumé, which sets forth additional facts regarding my professional background and affiliations, qualifications, experience, publications and presentations, is included as Appendix A.

The material I have reviewed and considered in my evaluation includes the following: the Hoagland Declaration and associated exhibits, which include the 1983 Consent Decree; the December 31, 1985 Affidavit of David M. Webster; engineering reports and addenda regarding the on-site and off-site recovery systems (these reports are listed in the Reference List included in this report); driller's logs for the recovery wells; water quality data regarding the on-site system and off-site monitoring wells; and the Certification of William S. (Pete) Duncan, III ("Duncan Certification").

As a result of my review and evaluation of the above-mentioned material, I have concluded that many of the problems associated with the operation of the on-site system and the inability to meet the performance standards described in the Hoagland Declaration result primarily from the fact that the hydrogeologic conditions encountered during the installation of the on-site system are significantly different from the conditions which were assumed to exist for the pre-design calculations. The hydraulic consequence of the differences between actual conditions and assumed conditions is that the estimated sustainable pumping rate for many of the wells and the areal extent of the region within which groundwater flow is diverted back to the recovery well system are less than was predicted in the pre-design calculations. I have also concluded that, notwithstanding the differences in site conditions which affect the system performance, the technically incorrect definition of "zone of influence" as contained in the Consent Decree has created a system performance standard which cannot be met. It is also my opinion that, when operating, the on-site system has been effective in removing contaminated groundwater from beneath the SRSNE site, and has likely prevented off-site migration of contaminated groundwater from the SRSNE site.

PERFORMANCE STANDARD FOR THE ON-SITE SYSTEM

In 1983, Solvent Recovery Services of New England (SRSNE) entered into a Consent Decree with the US EPA to address subsurface contamination which resulted from SRSNE operations at their Southington, Connecticut facility. One requirement of the Consent Decree was that SRSNE install an on-site multi-point shallow well system. The on-site system was to be constructed as close as possible to the eastern and part of the southern property boundaries of the SRSNE facility. The design of the on-site system was based on a preliminary design described by Wehran Engineering as a result of their field investigation and remedial action feasibility study (Wehran, 1982). The Wehran study was relied on during the negotiation of the Consent Decree (Hoagland Declaration Exhibit 8, p. 3). Final engineering design and specifications were developed by York Wastewater Consultants, Inc. (YWC) and Loureiro Engineering Associates, Inc. (Hoagland Declaration Exhibits 8 and 10).

The objective of the on-site system was to "prevent the off-site migration of subsurface contaminants, and consistent therewith, to extend its influence to the maximum practicable extent to off-site contamination" (Consent Decree, Paragraph 8(A)). From a hydrologic point of view, the objective means that operation of the on-site system was to cause groundwater at the eastern and part of the southern boundaries of the property to flow toward and be captured by the on-site system. If groundwater flow from those boundaries was toward and captured by the on-site system, off-site migration of subsurface contaminants would be prevented and the first part of the objective achieved. In addition, it was expected that the hydraulic effects of the pumping wells would extend beyond the property boundaries and influence, or affect, water levels downgradient of the property boundaries. Consequently, the second part of the objective was that the hydraulic effects of the pumping wells should extend as far off-site as reasonably possible.

It was recognized by EPA that the actual hydraulic effects of pumping from the on-site system may differ significantly from those predicted during the system design and before the system was constructed because the estimated conditions used to predict system performance would not necessarily reflect actual field conditions (Webster Affidavit, Paragraphs 11 and 12). Consequently, the Consent Decree also required that a monitoring system be installed to evaluate system performance.

One point of significant confusion which I have detected during my review of the reports and documents regarding the on-site system is the inconsistent use of the term "cone of influence" or "influence" of the recovery well system. This is an important issue because the definition of "cone of influence" as contained in the Consent Decree is inconsistent with the accepted scientific definition of the term. To understand the significance of this issue, one must understand the differing effects that a pumping well can have. In the area immediately around the well and for some distance away, a pumping well will capture groundwater and draw it into the well. This region is commonly referred to as the zone of capture of the well. At some further distance, the pumping well will lower the groundwater level but it will not draw groundwater from that area into the well. This region is commonly referred to as the cone of influence or zone of influence. The zone of influence of a pumping well or group of wells is correctly defined as the area within which water level declines (i.e. lowering of groundwater levels) occur as a result of pumping water out of the ground. The zone of influence is also referred to as the zone of drawdown or zone of depression (Todd, 1980, p. 115). Calculating the zone of influence of one or more pumping wells does not require explicit consideration of the natural slope of the water table, and the definition does not require or imply that all groundwater within the zone of influence or zone of drawdown be drawn toward the well. For the remainder of the report, I shall use the term "zone of influence" to refer to the region within which groundwater levels are lowered in response to pumping.

The Consent Decree defines "cone of influence" in Paragraph 4(B). That definition is "'Cone of Influence' or 'influence' shall mean the potentiometric surface around the pumping groundwater recovery system such that the hydraulic gradient is in the direction of the pumping wells". This is not a technically correct definition of the zone of influence, but rather a definition of what is typically referred to as a "zone of capture". That is, the zone within which water is captured by the pumping wells. The extent of the zone of capture is affected by the natural slope of the water table. The steeper the water table slope under non-pumping conditions, the closer the downgradient limit of the zone of capture of the pumping well. Because the extent of the zone of capture is affected by the water table slope, the downgradient extent of the zone of capture is always less than the downgradient extent of the zone of influence. The difference between the zone of capture and the zone of influence is significant with respect to the SRSNE on-site system because it appears that EPA is requiring the zone of influence calculated prior to construction of the on-site system (Hoagland Declaration Exhibit 10, Drawing 3) to be the region within which groundwater flow is to be toward the pumping wells (Hoagland Declaration, Paragraph 35).

This requirement is improper for two reasons. First, the calculated region of drawdown is a pre-construction prediction. As mentioned previously, EPA was aware and recognized that site conditions were likely to be different from those assumed in the calculations. Consequently, EPA recognized in 1985 that the actual region of drawdown would likely be different from the pre-construction calculated region of drawdown. This topic will be discussed in more detail in the following section. Notwithstanding the differences between actual and assumed site conditions and their consequences with respect to system operation, use of the YWC calculated zone of influence to define the region within which groundwater flow is to be directed toward the pumping wells is also technically incorrect and creates a performance standard which cannot be met. It is incorrect to use the YWC-calculated zone of influence to represent the region within which groundwater flow is to be directed toward the pumping wells because the YWC calculations did not consider the effects of the slope of the water table on determining the downgradient extent of the zone of capture. Wehran (1982) has prepared four maps which show the natural slope of the water table at the SRSNE site.

Figures 1 through 3 have been prepared to illustrate how the calculated zone of influence and the natural water level slope are combined to determine the zone of capture of the pumping wells. Figure 1 is a copy of the zone of influence contained in the YWC report (Hoagland Declaration Exhibit 10, Drawing 3). Figure 2 is a copy of the water table contour map for March 11, 1980 (Wehran, 1982, Sheet 3). March 11, 1980 is one of four dates for which such maps have been prepared by Wehran (1982). Figure 2 shows the water table elevations under non-pumping conditions. The procedure for determining the expected water levels under pumping conditions is to superimpose the calculated drawdown onto the non-pumping water level map. The calculated drawdown is arithmetically combined with the non-pumping water level and an expected pumping water level is calculated. Figure 3 illustrates the result of combining Figures 1 and 2. The resultant map is used to interpret the region within which flow is toward the pumping wells. The zone of capture as indicated on Figure 3 is the region within which flow is predicted to be toward the pumping wells. The zone of capture as shown on Figure 3 does not extend as far downgradient of the SRSNE site as does the zone of influence shown on Figure 1.

It is unusual to encounter conditions where the water table does not slope. It should be expected, therefore, that the zone of capture and the zone of influence would not be the same. In other words, the natural water level conditions limit the extent of the zone of capture of the pumping wells and make it impossible for the zone of capture to coincide with the zone of influence.

SITE CONDITIONS ARE NOT AS WERE ASSUMED IN THE YWC ANALYSES

As mentioned previously, EPA recognized in 1985 that actual site conditions were not likely to be as were assumed in the YWC calculations (Webster Affidavit, Paragraphs 11 and 12). In fact, the site conditions, both in the representation of the geology and the hydraulic response to pumping, are different than assumed in the YWC analyses. The hydraulic consequence of the differences between assumed and actual conditions is to result in a lower sustainable pumping rate from the recovery well system, particularly in the southern portion of the system, and a less extensive zone of influence and zone of capture of the pumping wells.

The depth to bedrock along the line of the recovery well system is not as deep as was assumed in the YWC analyses. Figure 4 illustrates the subsurface conditions which were expected and encountered along the location of the on-site system. The figure also illustrates the elevations of the individual extraction wells and their screened intervals. The actual bedrock elevation and well construction details are based on information contained in Hoagland Declaration Exhibit 17. Figure 4 also illustrates the water table and bedrock elevations assumed by YWC for the drawdown analyses they did prior to construction of the recovery well system (Hoagland Declaration Exhibit 10, Drawing 2). With three exceptions, bedrock was encountered at a shallower depth than initially assumed. There are several consequences of this deviation from expected conditions:

1. The actual well depths were less than was expected. In many instances, the depth to bedrock elevations was five feet less than was expected and for two wells (wells 1 and 2), bedrock was encountered thirty feet higher than expected. Because bedrock was encountered at a shallower depth than expected, the final well depths were less than expected.

2. Wells 1 and 2, which were installed about three feet into the bedrock, are about four to eight feet above the June 1981 water table elevation. This means that it is

likely that at least part of the year, and perhaps all of the year, the water table elevation is below the bedrock surface and below the bottom of the well. Consequently, there is little, if any, groundwater flow in the unconsolidated deposits and these wells cannot pump water continuously.

3. The saturated thickness of the unconsolidated deposits is less than was expected in the YWC analyses. As a result, the amount of available drawdown, the sustainable pumping rate, and the likely extent of the zone of influence are less than was estimated by YWC.

In addition to the differences between expected and actual bedrock depth, the YWC calculations were also based on hydraulic conditions which are different from those encountered at the location of the on-site recovery well system. The consequence of the differences in hydraulic conditions is to result in a lower sustainable pumping rate from the recovery well system and a less extensive zone of influence of the pumping wells.

One of the major differences between the conditions assumed in the YWC calculations and actual hydraulic conditions is the reduction in the ability of water to move through the ground as a result of water level declines due to pumping. The YWC analyses assumed that the water level changes due to pumping would not reduce or limit the ability of water to flow through the ground in the vicinity of the pumping wells. The drawdown calculations which are described in the YWC report (Hoagland Declaration Exhibit 8, p. 9-14) are based on what is referred to as the Theis non-equilibrium formula. The Theis formula was developed in 1935 and is based on several simplifying assumptions (Ferris et al., 1962, p. 92-98). One of the assumptions is that the transmissivity is constant at all times and places. Transmissivity refers to the ability of water to move through the ground and is the product of two other hydraulic conditions. One is the permeability of the saturated earth material and the other is the thickness of the saturated material. For water table conditions, such as found at the SRSNE site, the lowered water levels result in a reduced saturated thickness which consequently results in a reduced transmissivity. The YWC analyses did not consider that the water level changes or drawdown in the vicinity of the pumping wells would result in a reduction of the transmissivity of the material around the pumping wells. The YWC analyses assumed a constant transmissivity for the 30-day pumping condition evaluation. The YWC evaluations calculated that water level declines in proximity to the recovery well system would be about 7.75 feet in the central portions of the well system and about 5.2 feet at the edges of the system (Hoagland Declaration Exhibit 8). The YWC-calculated water level decline is about half the available saturated thickness between the water table and the bottom of the well screen for the on-site system.

Table 1 lists the height of water above the bottom of each of the recovery wells. The water column height is the difference between the water table elevation reported for June 16, 1981 (Hoagland Declaration Exhibit 10, Drawing 2) and the elevation of the bottom of the well screen. The YWC-calculated drawdown of 5.2 to 7.75 feet represents a substantial portion of the available saturated thickness. A significant reduction in the water transmitting properties of the overburden and upper bedrock would occur as a result of the water level lowering. The reduction in water transmitting properties caused by the reduction in saturated thickness would result in even greater drawdown along the line of pumping wells than was calculated by YWC.

I have reviewed the YWC analyses and done similar calculations but considered the effects of reduced transmissivity resulting from water level lowering. All other conditions were as assumed in the YWC calculations. My calculations indicate that drawdown in the vicinity of the central portion of the on-site system would exceed 12 feet and at the edges of the system would exceed 8 feet. The revised calculated drawdown which considers the effects of water table lowering on the ability of water to flow through the ground is about 50 percent greater than calculated by YWC. The calculated drawdown represents a substantial portion of the available drawdown at the pumping wells. The increased drawdown which resulted because of actual site conditions probably caused several wells to dry up and restricted the amount of water which could be pumped from some wells.

The reduction in saturated thickness and the consequent reduction of transmissivity and sustainable well yield is a significant hydrologic condition which affects the amount of water which can be pumped from the on-site recovery system. Notwithstanding any improvements which might be made in the operation and maintenance of well pumps, it appears that the actual site conditions will significantly restrict the sustainable yield from many of the wells.

ANALYSIS OF WATER LEVEL DATA

The available water level data for each of the recovery wells were reviewed for evaluating the operation of the on-site system. Water level data analysis for these wells is not straightforward because of several complicating factors. One factor is that all measurements are reported as deviations from a "baseline" condition. The baseline water level measurement is the average of three measurements made during January 1986 (Hoagland Declaration Exhibit 19). If the actual elevation of the baseline measurement were known, all subsequent measurements could also be determined. Inconsistencies, or uncertainties, regarding well construction data preclude determination of baseline elevations for all wells. Consequently, the water level analysis was made by comparing water level changes with respect to the baseline conditions.

Figures 5 through 29 are graphs of water level change for each of the recovery wells which are part of the on-site system. The horizontal axis of the graphs is a time scale and indicates the date of the measurements. The vertical scale indicates the water level change from the baseline condition. The baseline gauge reading which corresponds to the zero position on the vertical axis is listed on the bottom left corner of each figure. Negative water level change indicates that the measured water level was lower than the baseline water level. Positive water level change indicates that the measured water level was higher than the baseline water level. Negative water level changes which are equal in magnitude to the baseline gauge reading indicate that the measured water level was at or below the measuring point which is at the bottom of the well.

To aid evaluation of the recovery well water level data, a graph of water levels measured in a U.S. Geological Survey ("USGS") monitoring well was made (U.S. Geological Survey, 1988, 1989). The well, which is referred to by the USGS as WB 198, is part of a state-wide water level monitoring network. Well WB 198 is the closest USGS monitoring well to the SRSNE facility. The well is 31 feet deep and constructed in glacial till, the same type of material which is found at the SRSNE site. The well is reportedly unused except for the purpose of making water level measurements. Water level data for this well were considered to be an estimate of the seasonal range in water levels which might be expected to occur at the SRSNE site under non-pumping conditions. Figure 30 is a graph of the water level measurements reported for the period October 1985 through September 1987. The data indicate that the January 1986 water level measurement is about the middle of the range of water level fluctuation for the reporting period. This suggests that the on-site system baseline water level measurements probably represent an average water level condition. The graph also indicates that the 1987 water levels were slightly higher than the 1986 water levels.

Water level data for the on-site recovery wells reflect both the effects of pumping and seasonal water level changes, and it is not possible to directly determine how much of the change is due to pumping and how much is due to seasonal water level variations. Water level data from USGS monitoring well WB 198 suggest that natural water level fluctuations may be about four feet above and below the baseline elevation. Regardless of the inability to differentiate what portion of the observed water level changes in the recovery wells is due to pumping, it is clear that water levels in many of the wells were much lower than were previously expected (Hoagland Declaration Exhibit 10, Drawing 2). Drawing 2 indicates that the expected water level in the pumping wells would range between about 10 to 20 feet above the bottom of the recovery well. Twenty three of the 25 recovery wells had one or more measurements which indicated that water levels were at or below the well bottom. For some of the wells, such as 1, 2, 4, 14, 15, 19, and 23, there were several measurements which indicated that water levels were at or below the well bottom.

The condition of lowered water levels would limit the amount of water which could be pumped from the well. The resulting reduction in the pumping rate would limit the extent to which the effects of pumping would extend off-site, but would not necessarily preclude the system from preventing off-site migration of subsurface contaminants. That is, even though pumping rates from several of the wells were less than estimated in the pre-construction calculations, the actual pumping rates and associated drawdown may have been sufficient to cause groundwater at the property boundary to flow toward the pumping wells instead of flowing off-site.

The water level contour maps contained in the Wehran report (1982, Drawings 2, 3, 4, and 5) indicate that the difference in water level elevation between the location of the on-site recovery wells and the downgradient property boundary ranges from about 0.3 to 1.5 feet. To reverse flow from the downgradient property boundary toward the pumping wells, it would be necessary for the pumping to cause a differential water level change of 0.3 to 1.5 feet. Based on my review of the water level data and understanding of site conditions, it is my opinion that when the wells were pumping the differential water level change resulting from the pumping was sufficient to cause groundwater at the property boundary to flow toward the pumping wells. It is also my opinion that the reduced pumping rate from many of pumping wells which resulted from greater than anticipated water level decline would limit the maximum practicable extent to which the effects of pumping could extend off-site.

ANALYSIS OF WATER QUALITY DATA

I have also reviewed water quality analyses of the recovery system discharge and off-site monitoring wells TW-7A, TW-7B, and TW-8A. Water samples were collected from the recovery well system discharge on a bi-monthly basis between 1986 and 1989 (YWC NPDES Permit Discharge Reports). Water samples were collected on several occasions from monitoring wells TW-7A, TW-7B and TW-8A between 1980 and 1989 (Wehran, 1982, Appendix E; YWC, 1984b, Tables 3-1 and 3-6 through 3-16; Hoagland Declaration Exhibit 14).

Review of the recovery system discharge data (the influent to the treatment system) indicates that from 1986 through 1989 the total volatile organic concentrations were on the order of 100 parts per million (ppm). This indicates that the system has been effective in collecting contaminated groundwater from beneath the SRSNE site. The average daily 1989 discharge rate from the system was estimated to be about 9,500 gallons per day (gpd) (Hoagland Declaration, Paragraph 73). Combining the average discharge rate with the estimated TVO concentration of about 100 ppm, and assuming an average specific gravity of 1.0 for the organic compounds, indicates that in 1989 the system was removing about 8 pounds of volatile organic compounds per day.

A summary of the water quality data for wells TW-7A, TW-7B, and TW-8A is contained in Tables 2 through 4. The summary tables include those compounds identified in the Consent Decree (Paragraph 6) as having specified cleanup levels. The monitoring wells are located east of the SRSNE facility between the on-site recovery system and the Quinnipiac River. Review of the limited monitoring data indicates that the concentrations of almost all of the chemicals listed in the tables have decreased.

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Vice President, Harvard Office
Principal Hydrogeologist
GeoTrans, Inc.

Professional Expertise:

Hydrogeology
Modeling groundwater systems
Solute transport analysis
Multiphase flow analysis
Hydrogeologic field investigations
Monitoring groundwater systems
Aquifer test design and analysis

Education:

Ph.D., Geology, The Pennsylvania State University, 1976
M.S., Geology, The Pennsylvania State University, 1969
B.A., Geology, Franklin and Marshall College, 1967

Professional Experience:

1985-Present
Principal Hydrogeologist, Vice President, GeoTrans, Inc., Harvard, Massachusetts

1984-1985
Roy F. Weston, Inc.

1981-1984
Arthur D. Little, Inc.

1974-1981
U.S. Geological Survey, Water Resources Division
(Boston, MA, and St. Paul, MN)

Relevant Project Experience:

Dr. Guswa has extensive experience in field investigations of groundwater hydrology and the application of analytical and numerical models to simulate aquifer systems. He has been responsible for planning and directing programs for regional and local groundwater resource evaluation; supervision of deep and shallow test well drilling and sampling programs; design and supervision of aquifer testing, monitoring and analysis programs, development and application of groundwater flow, energy and chemical transport models; identification of contaminant plumes and assessment of groundwater contamination. He has provided expert opinion and testimony as part of settlement agreement discussions and litigation concerning groundwater contamination by hazardous wastes.

Key Projects:

Provided expert testimony and technical analyses related to the hydrogeologic factors which affect groundwater flow and contaminant transport from several hazardous waste disposal sites.

Developed a groundwater contamination response guide for the U.S. Air Force.

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Provided technical analysis and evaluations regarding hydrogeologic and regulatory considerations related to landfill siting, expansion, and closure.

Directed a project to develop a consistent analysis methodology for evaluating migration of coal-tar compounds from inactive waste disposal sites under various hydrogeologic settings.

Evaluated hydrodynamic, gravitational, and capillary pressure forces on the migration of an immiscible organic fluid. Developed and applied a multiphase flow model to aid design of a remedial plan for an inactive landfill. Provided technical evaluation of hydrogeologic issues in support of settlement agreement discussions.

Provided technical analyses regarding the nature and extent of soil and groundwater contamination resulting from leaking underground tanks and pipelines. Designed investigations and actions to remediate soil and groundwater contamination.

Directed hydrogeologic investigations related to identifying possible remedial actions for an inactive chemical waste disposal area.

Principal Investigator to review available hydrogeologic and geochemical data for areas being investigated by DOE as potential repositories for high level radioactive waste.

Principal Investigator to provide technical assistance to a European governmental agency regarding ground-water issues related to siting, monitoring, and evaluating sites for disposal of low and intermediate level radioactive wastes.

Consultant to Ministry of Agriculture and Fisheries, Sultanate of Oman regarding water resource appraisals.

Project Director for US Geological Survey groundwater resource appraisals of Cape Cod, Massachusetts and the Twin Cities metropolitan area, Minnesota.

Staff Geologist on U.S. Geological Survey project to map surficial geology of the Pepperell quadrangle in Massachusetts.

Professional Affiliations:

Association of Ground Water Scientists and Engineers of NWWA
Geological Society of America
American Geophysical Union
American Water Resources Association
Society of Petroleum Engineers of AIME
American Water Works Association
International Association of Hydrological Sciences
Association of Engineering Geologists, New England Section

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Table 1. Calculated water column lengths in recovery wells.

Well No.	Water Level Elevation[1]	Well Point Elevation[2]	Length of Water Column[3]
1	159.5	164.9	0
2	158.6	161.0	0
3	158.2	145.1	13.1
4	158.1	144.0	14.1
5	158.1	143.0	15.1
6	158.1	141.1	17.0
7	158.0	142.4	15.6
8	158.0	141.9	16.1
9	158.0	141.5	16.5
10	158.0	140.8	17.2
11	158.1	141.4	16.7
12	158.1	139.7	18.4
13	158.1	141.6	16.5
14	158.1	142.8	15.3
15	158.2	142.5	15.7
16	158.2	139.8	18.4
17	158.2	140.3	17.9
18	158.2	139.7	18.5
19	158.2	146.9	11.3
20	158.3	144.2	14.1
21	158.3	141.9	16.4
22	158.3	139.5	18.8
23	158.3	142.4	15.9
24	158.4	146.7	11.7
25	158.5	145.5	13.0

[1] Measured June 16, 1981 (Ref: Hoagland Declaration Exhibit 10, Drawing 2)
[2] Top of cover elevation (Ref: Hoagland Declaration Exhibit 18) minus depth to bottom of screen (Ref: Hoagland Declaration Exhibit 14, Attachment 7)
[3] Height of water table above bottom of well point

Table 2. Water Quality Data Summary
Well TW-7A

Compound	b 03/19/80	b 04/09/80	a 09/15/82	a,b 08/15/83	a 02/15/86	b 09/17/86	05/23/88	05/17/89
PCE	NR	NR	470	490.7	<10	<5	<5	<5
TCE	4	1.3	330	295.9	<10	<5	<5	<5
1,1,1 TCA	440	260	ND	131.7	<10	160	<5	<5
MEK	NR	NR	97000	30287	240000	290000	NR	NR
BENZENE	NR	NR	570	414	<10	370	<5	<5
VINYL CHLORIDE	NR	NR	NR	NR	20000	13000	25000	<10
1,1 DCE	ND	4.2	ND	484	<10	340	<5	<5
TOLUENE	NR	NR	30000	7857	37000	33000	39000	26000
ISOPROPYL ALCOHOL	NR	NR	98000	380004	210000	480000	<500	100
METHYLENE CHLORIDE	25	25	57000	19294	16000	8800	5000	3400 J
TOTAL TRIHALOMETHANES	NR	NR	NR	NR	NR	NR	NR	NR
1,4 DIOXANE	NR	NR	NR	NR	NR	<100	<500	18

Notes:
a - day of month estimated
b - listed as TW-7
NR - not reported
ND - not detected
J - estimated value

Table 3. Water Quality Data Summary
Well TW-7B

Compound	03/13/80	09/15/82 [a]	08/15/88	06/08/83 [a]	02/15/86 [a]	09/17/86	06/03/88	05/17/89
PCE	NR	ND	42.3	<10	<10	<5	<5	<5
TCE	800	ND	34.6	600	<10	<5	<5	<5
1,1,1 TCA	300	370	63.5	312	<10	190	<5	<5
MEK	NR	140000	27729	140094	160000	410000	NR	NR
BENZENE	NR	240	122.9	496	<10	380	<5	<5
VINYL CHLORIDE	NR	NR	NR	2641	4000	2000	<10	9300 J
1,1 DCE	ND	ND	52.5	68	<10	<5	<5	<5
TOLUENE	NR	13000	1109	15360	4000	21000	22000	30000
ISOPROPYL ALCOHOL	NR	220000	193656	116313	210000	460000	<500	110
METHYLENE CHLORIDE	4000	ND	2299	383	3300	630	3000	4100 J
TOTAL TRIHALOMETHANES	NR	NR	NR	NR	NR	NR	NR	NR
1,4 DIOXANE	NR	NR	NR	ND	NR	<100	<500	20

Notes:
a - day of month estimated
NR - not reported
ND - not detected
J - estimated value

Table 4. Water Quality Data Summary
Well TW-8A

Compound	03/14/80	09/15/82 [a]	06/03/88
PCE	NR	2900	<5
TCE	>25000	40000	<5
1,1,1 TCA	11000	9600	6100
MEK	NR	170000	NR
BENZENE	NR	390	<5
VINYL CHLORIDE	NR	NR	<10
1,1 DCE	ND	210	<5
TOLUENE	NR	36000	25000
ISOPROPYL ALCOHOL	NR	230000	<500
METHYLENE CHLORIDE	>30000	57000	17000
TOTAL TRIHALOMETHANES	NR	NR	NR
1,4 DIOXANE	NR	NR	<500

Notes:
a - day of month estimated
NR - not reported
ND - not detected

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Additional Comments (optional):

ESize map is severely water damaged and started to tear when I tried to scan it.

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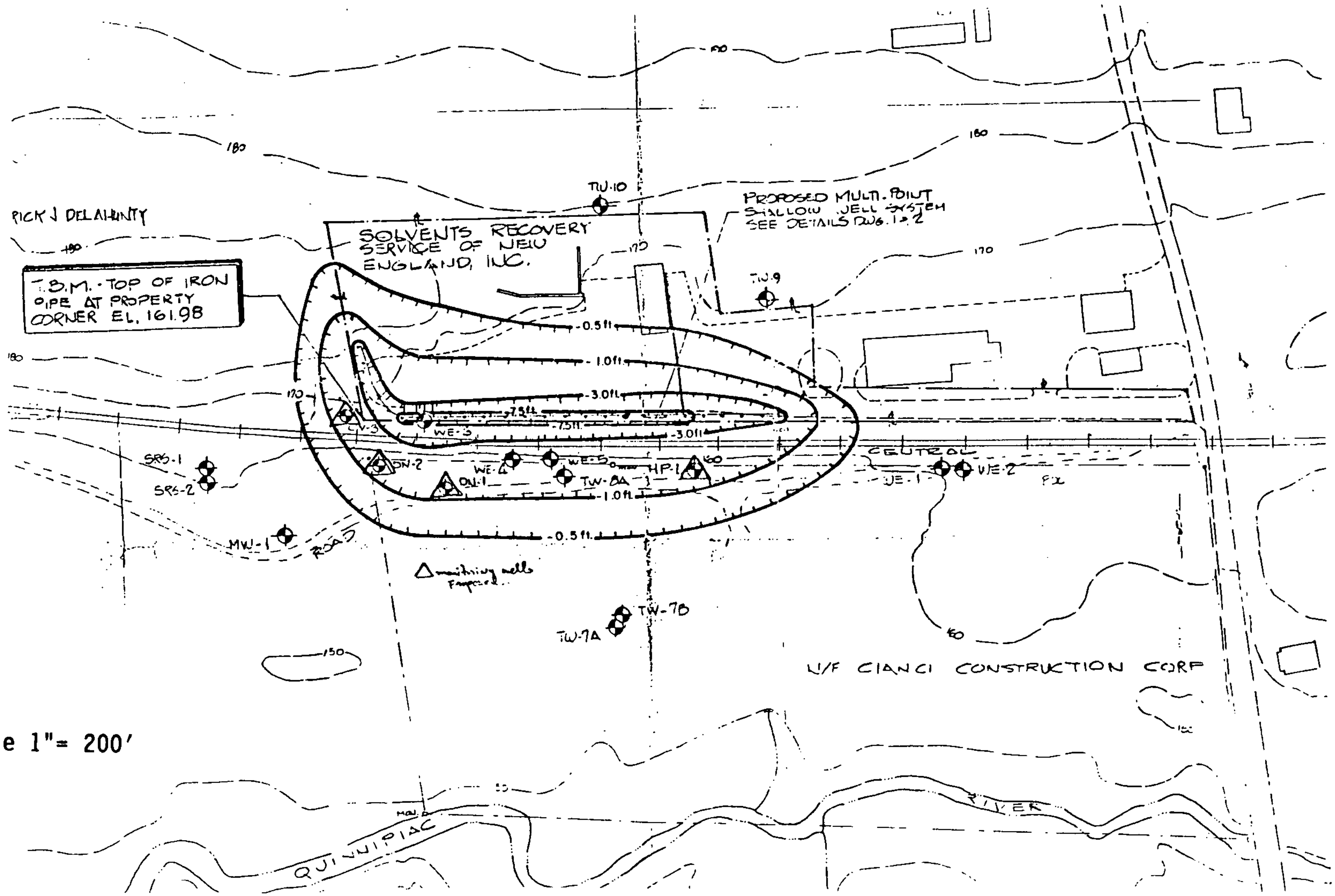

Scale 1"= 200'

Figure 1. Target zone of influence calculated by YWC
(Ref: Hoagland Declaration Exhibit 10, Drawing 3)

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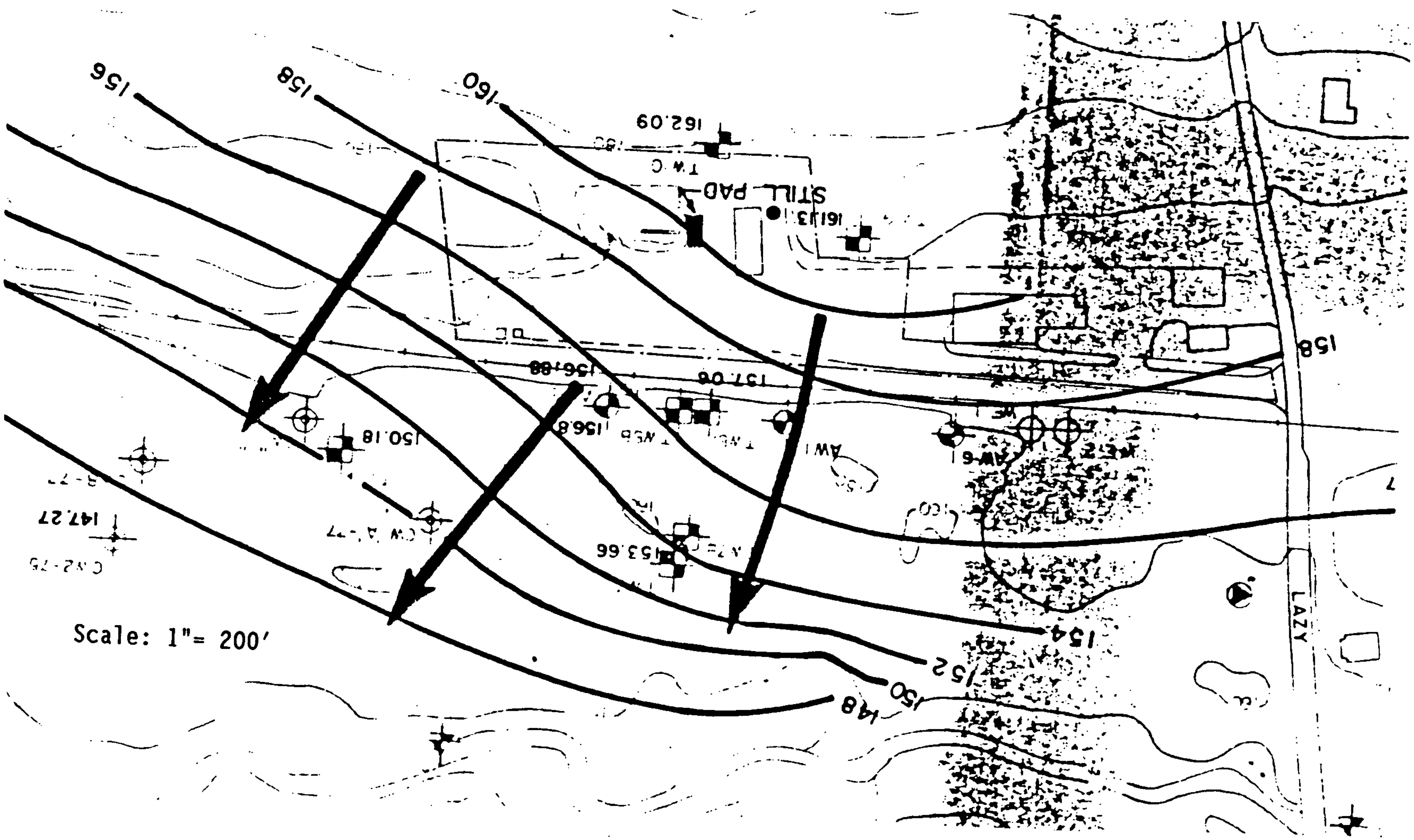

Figure 2. Water table contour map, March 11, 1980
(Ref: Wehran, 1982, Sheet 3)

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— · — Boundary of Zone of Capture

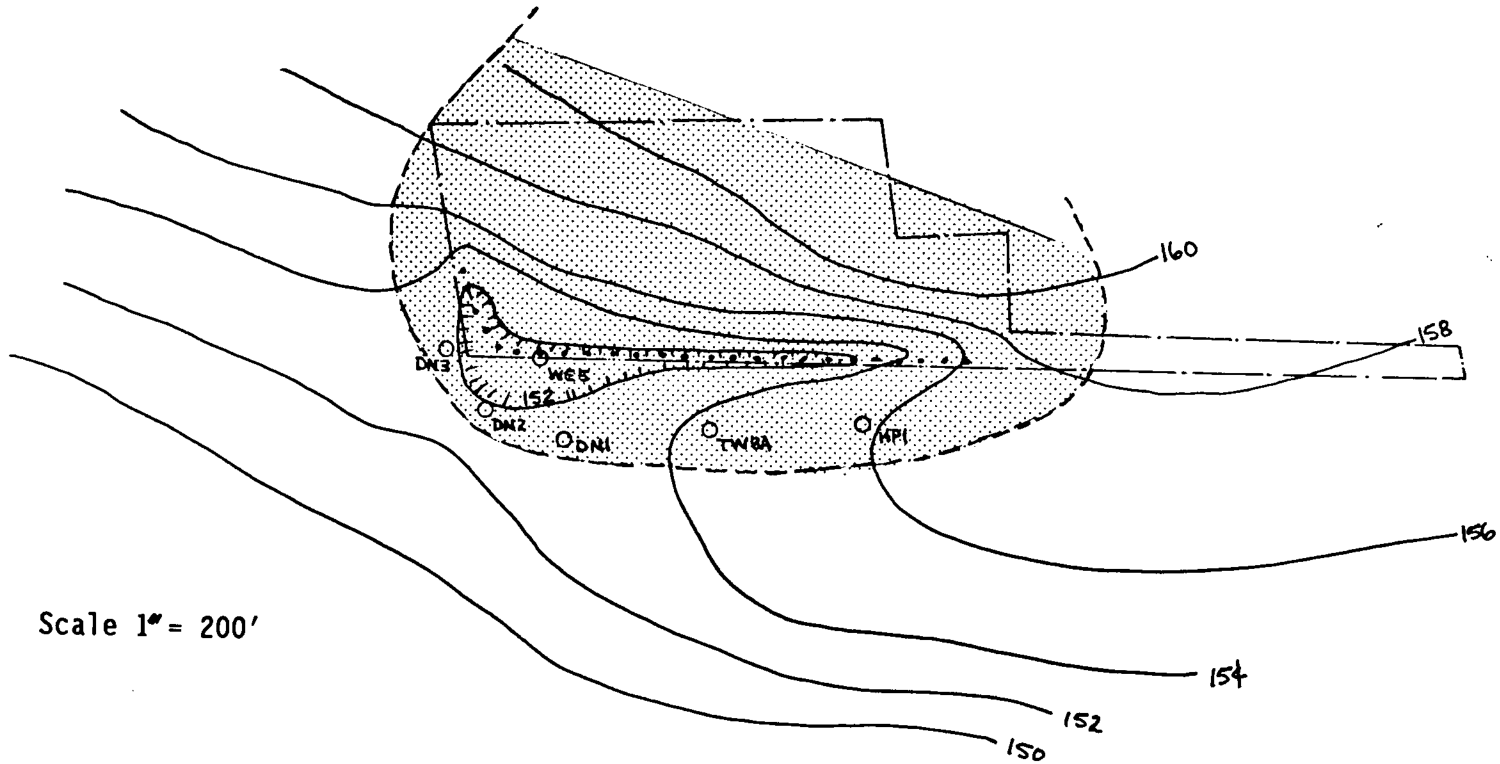

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Figure 3. Estimated zone of capture of on-site system based on the YWC calculated zone of influence and March 11, 1980 water elevations

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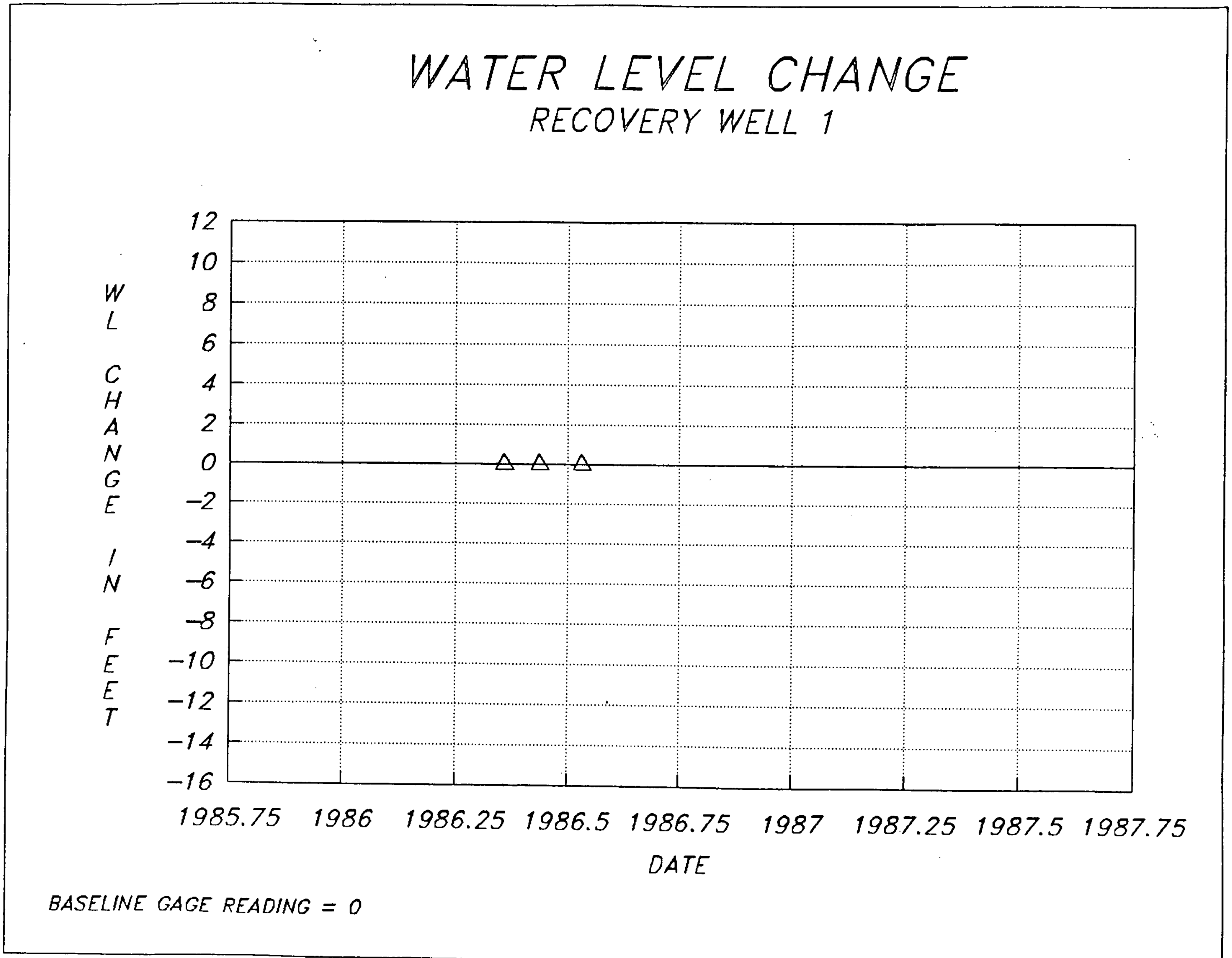

Figure 5. Water Level Change Recovery Well 1

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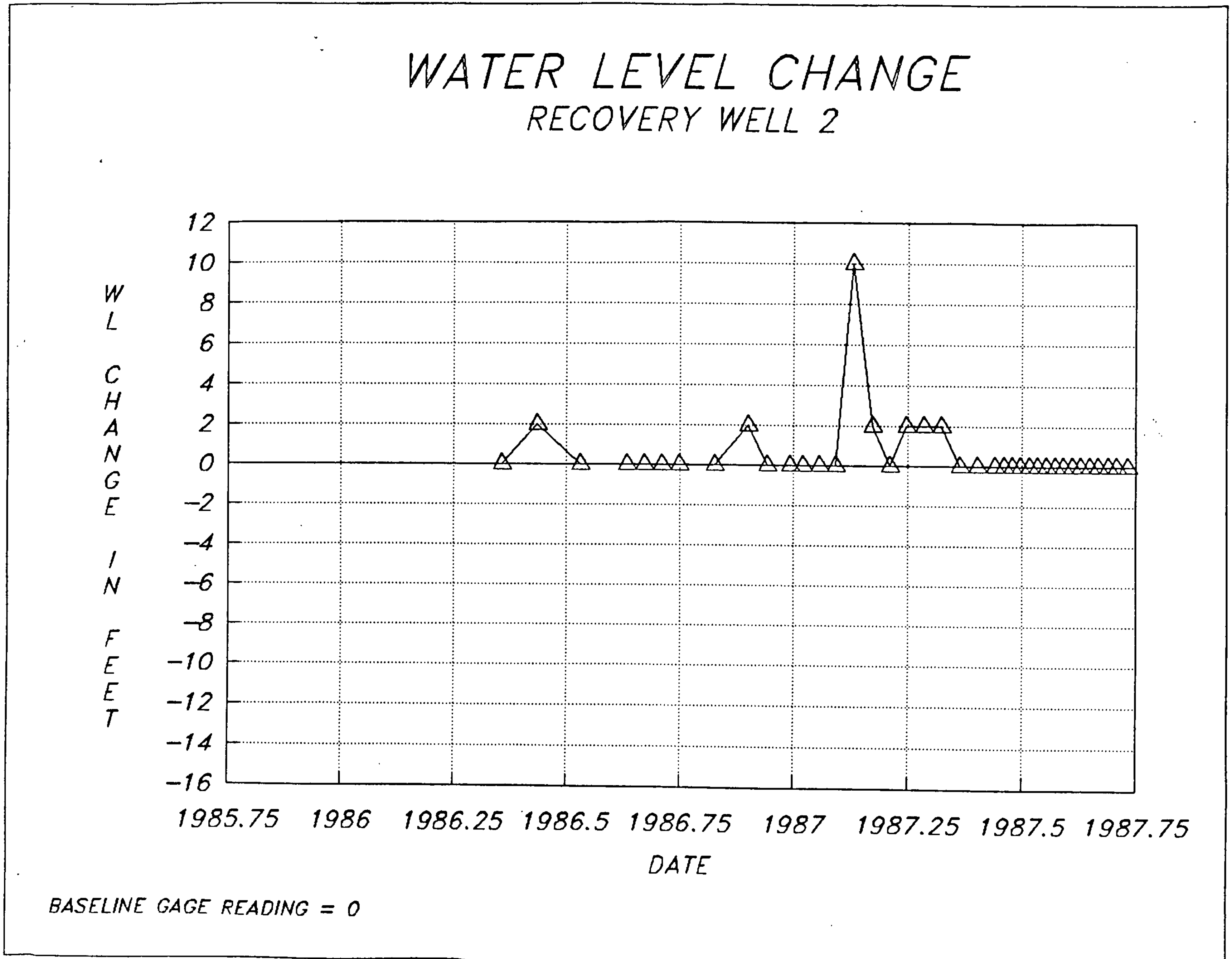

Figure 6. Water Level Change Recovery Well 2

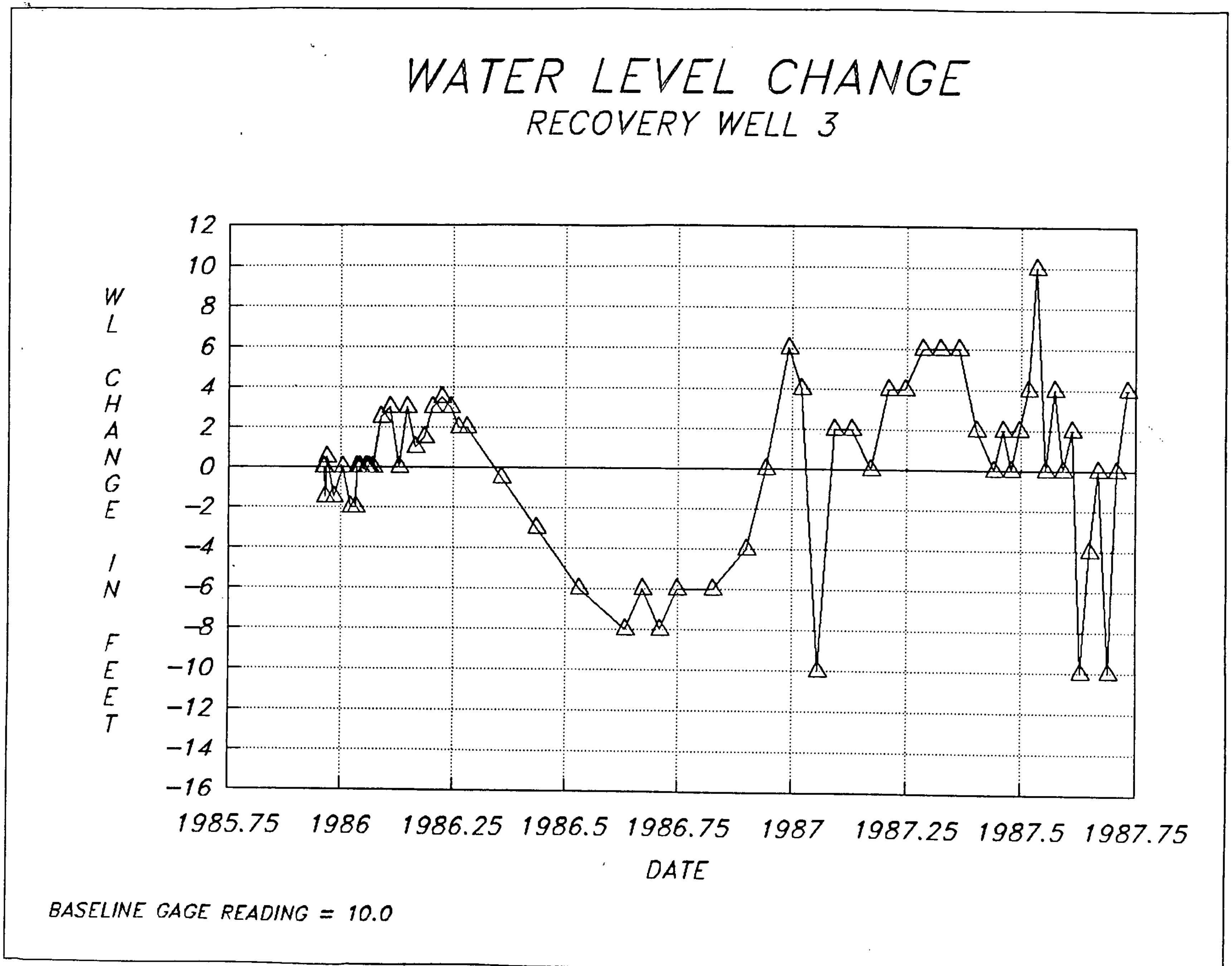

Figure 7. Water Level Change Recovery Well 3

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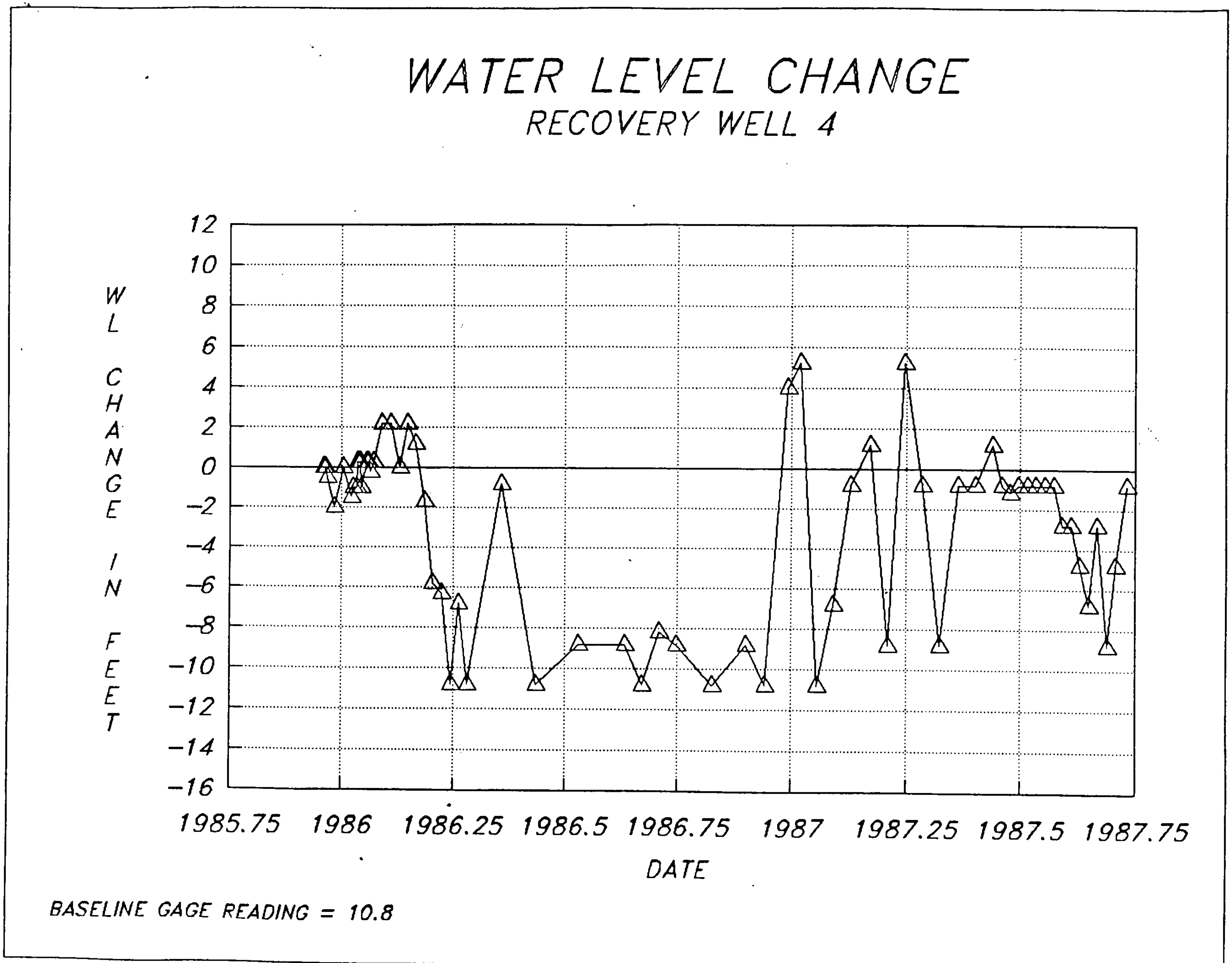

Figure 8. Water Level Change Recovery Well 4

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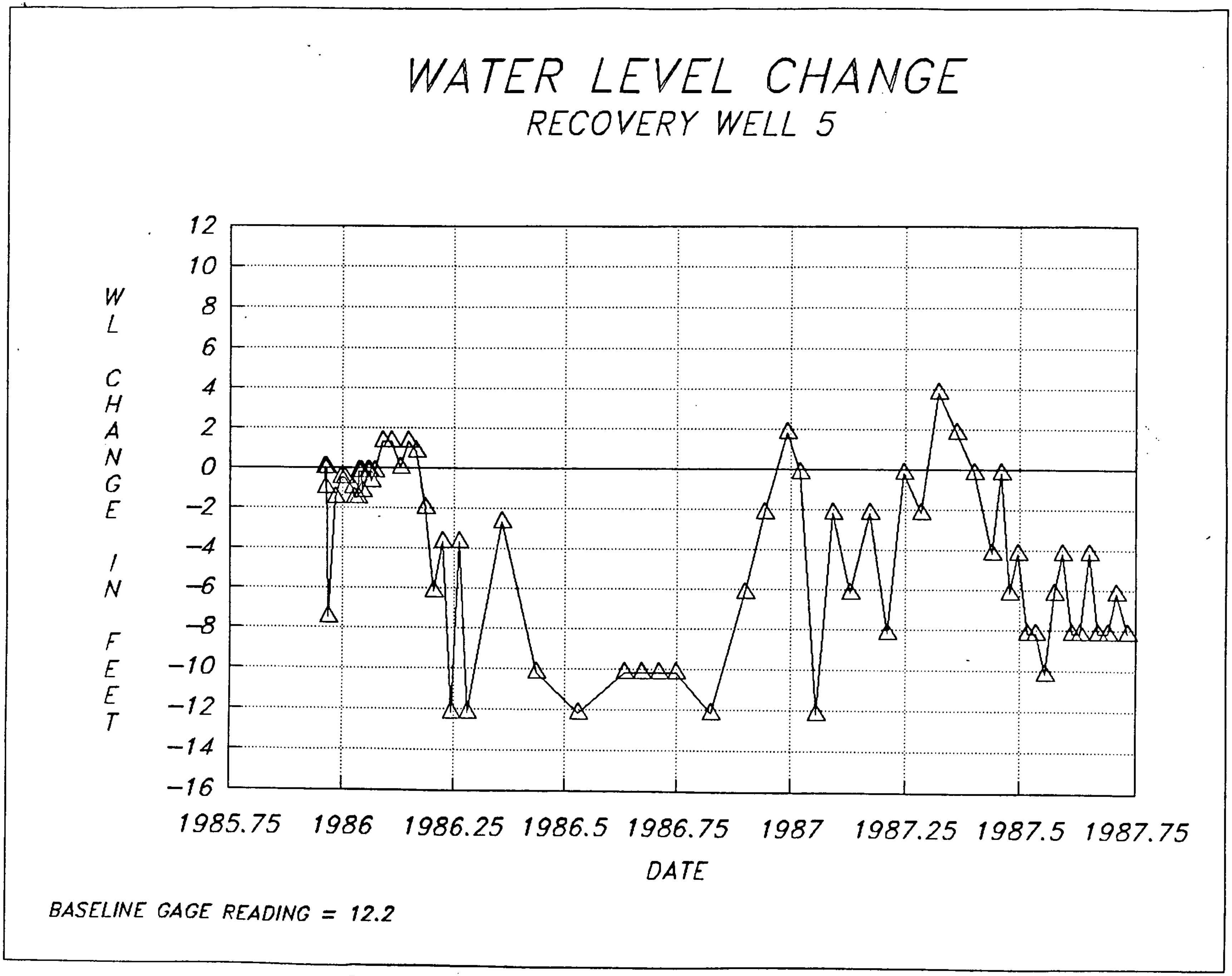

Figure 9. Water Level Change Recovery Well 5

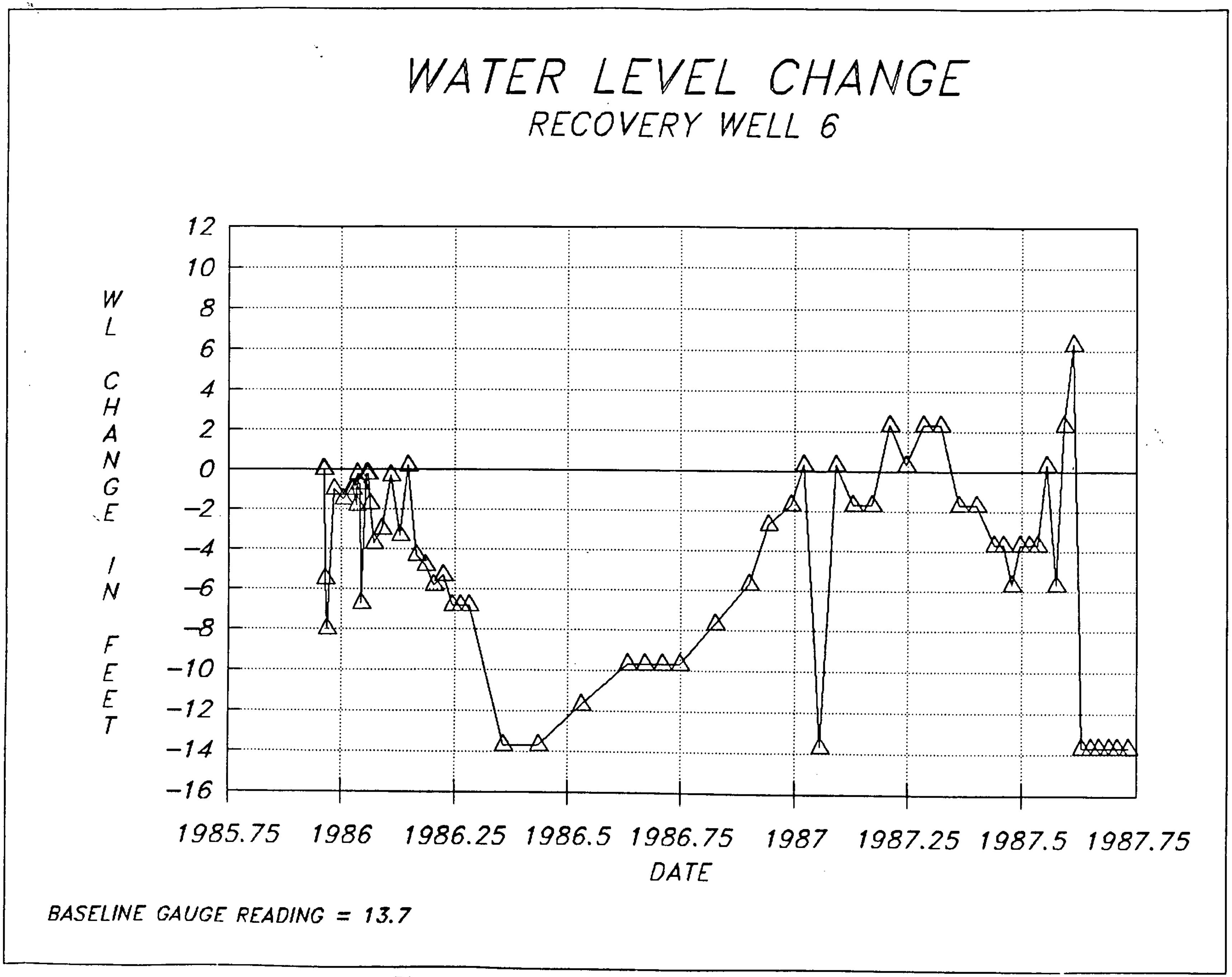

Figure 10. Water Level Change Recovery Well 6

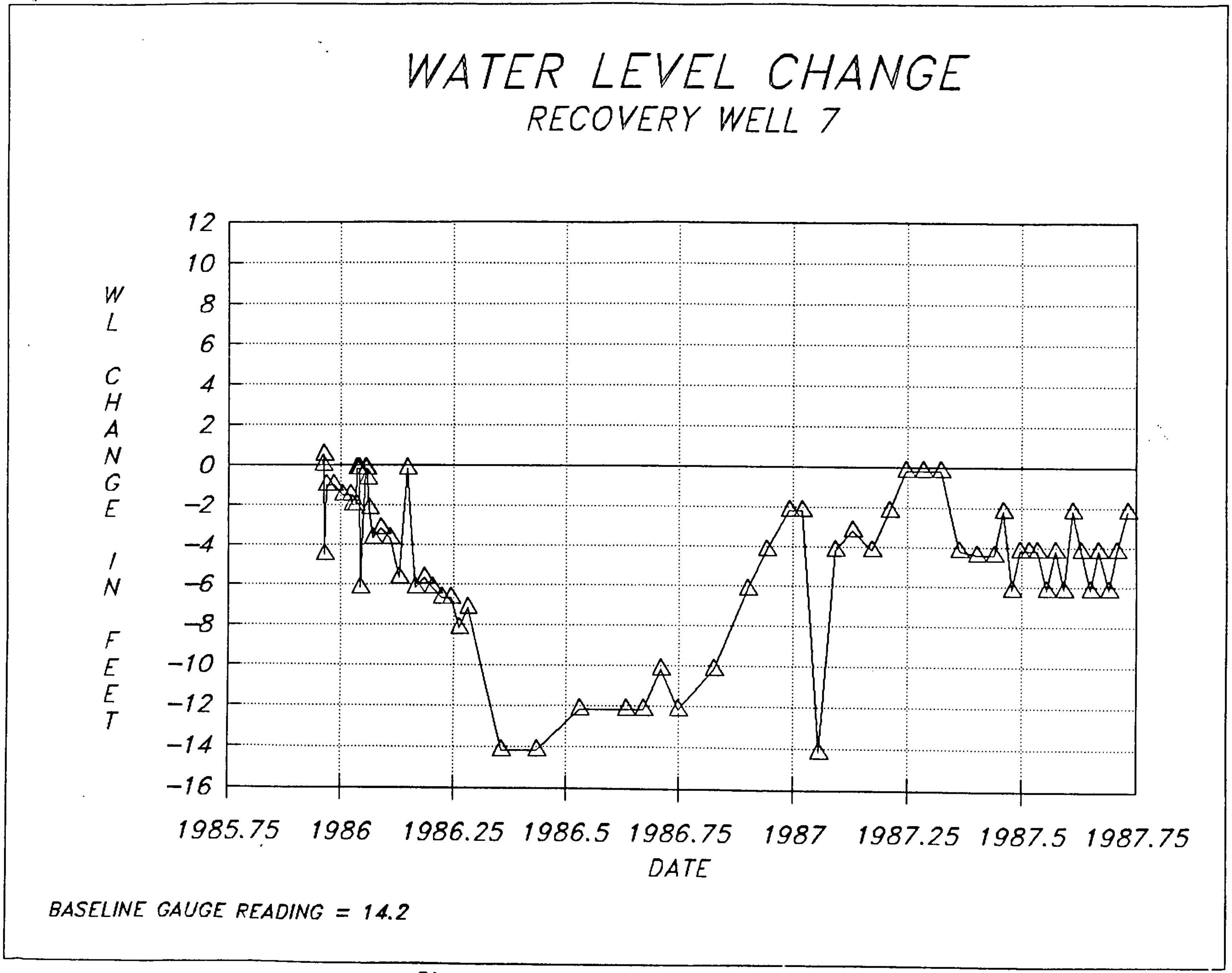

Figure 11. Water Level Change Recovery Well 7

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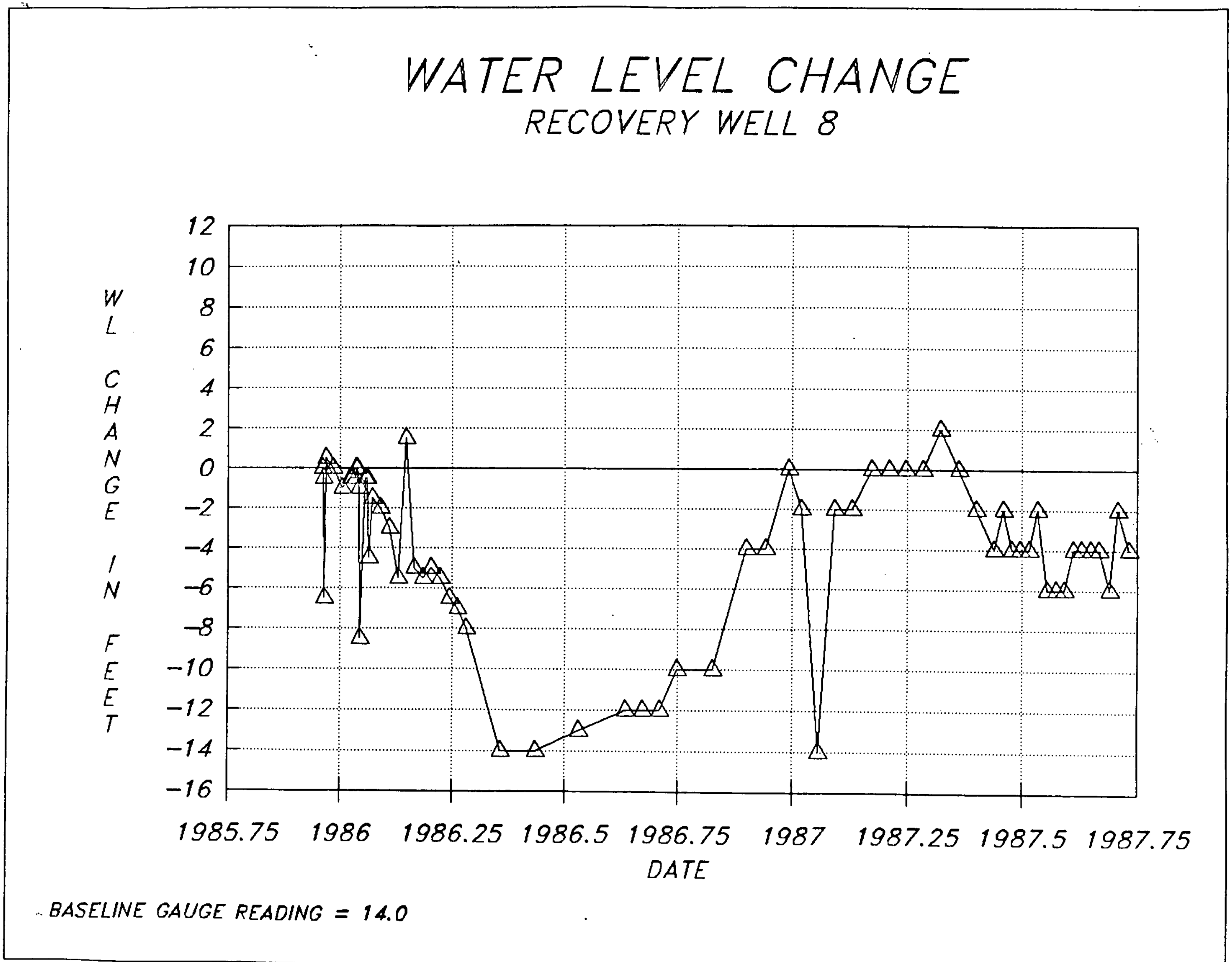

Figure 12. Water Level Change Recovery Well 8

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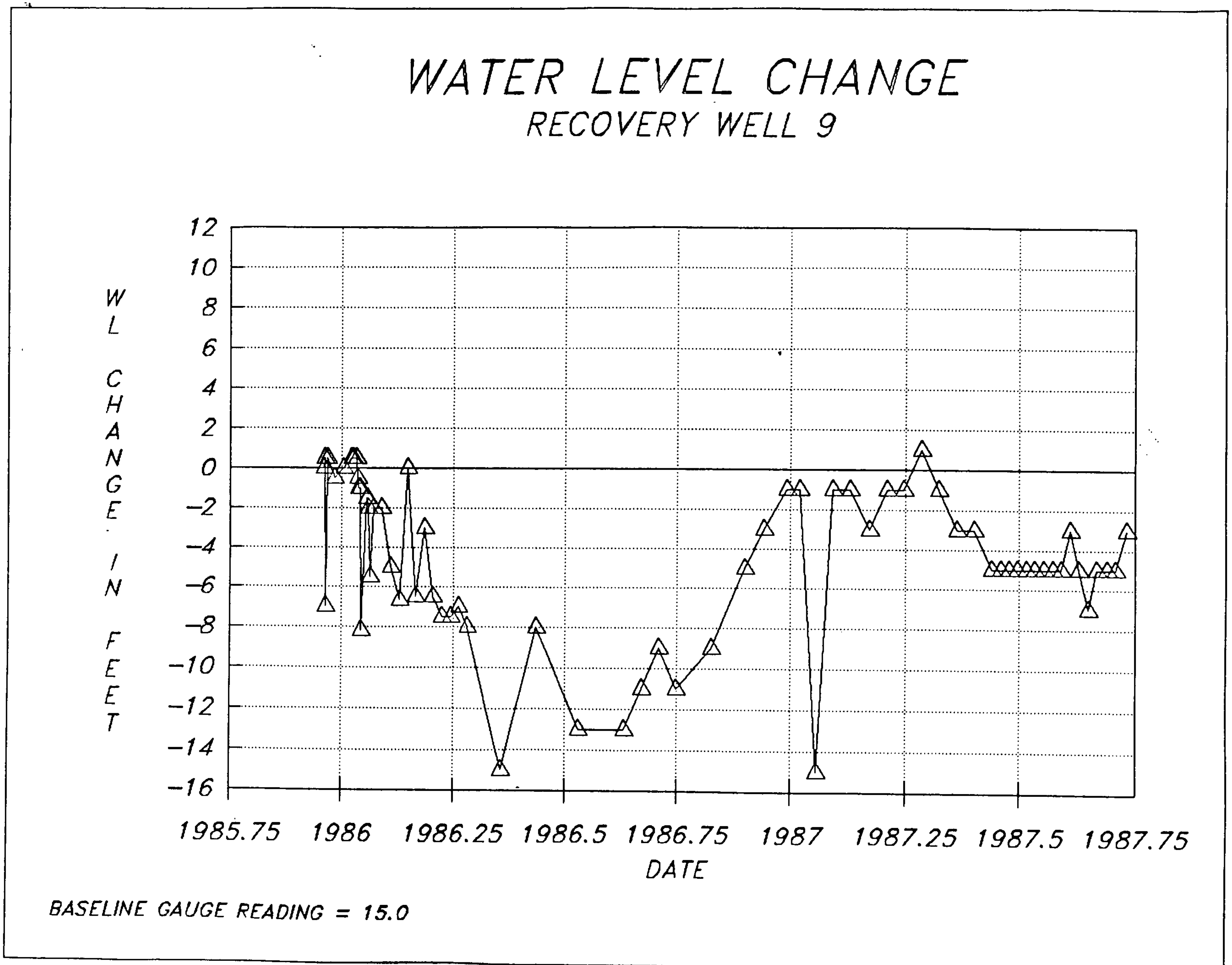

Figure 13. Water Level Change Recovery Well 9

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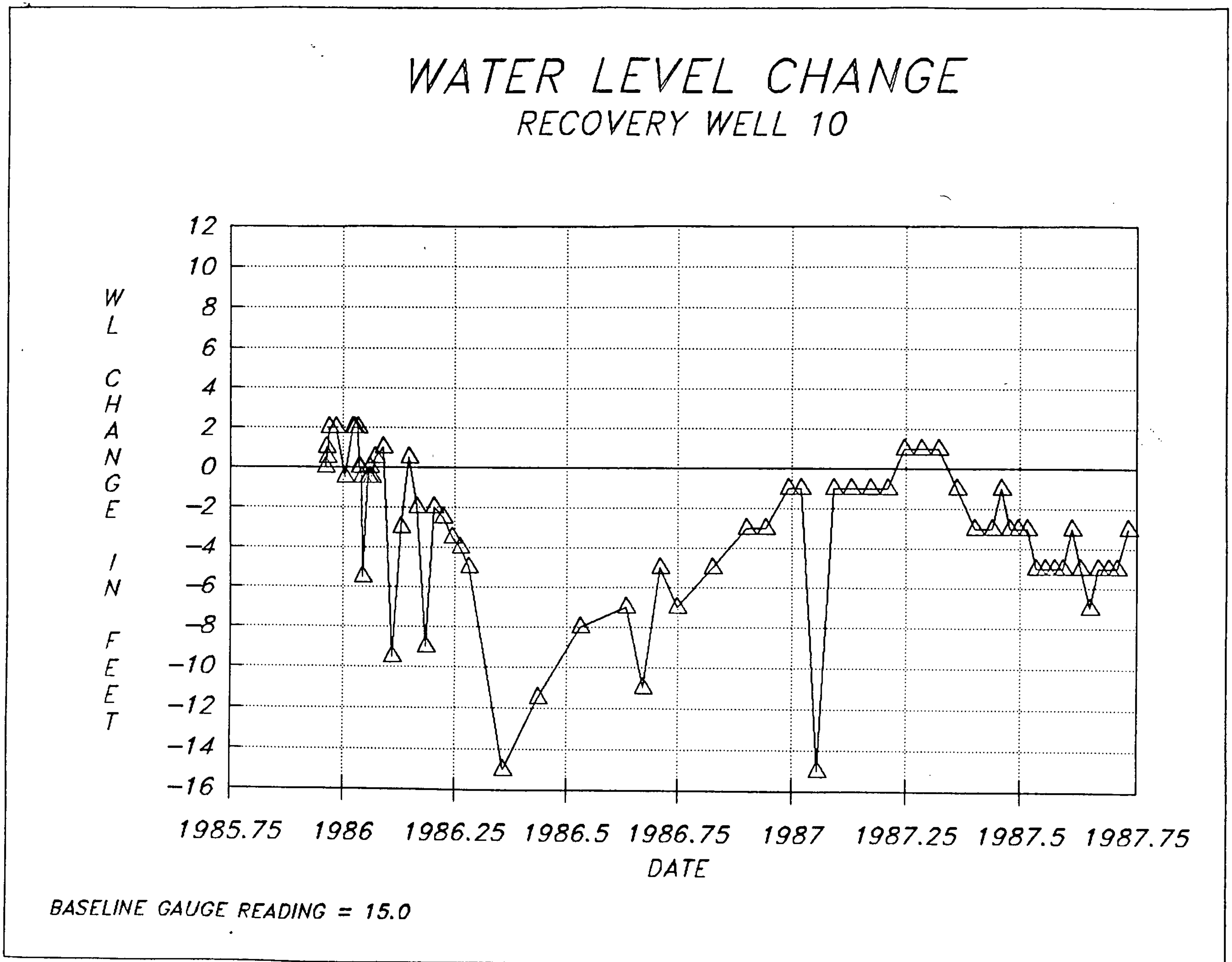

Figure 14. Water Level Change Recovery Well 10

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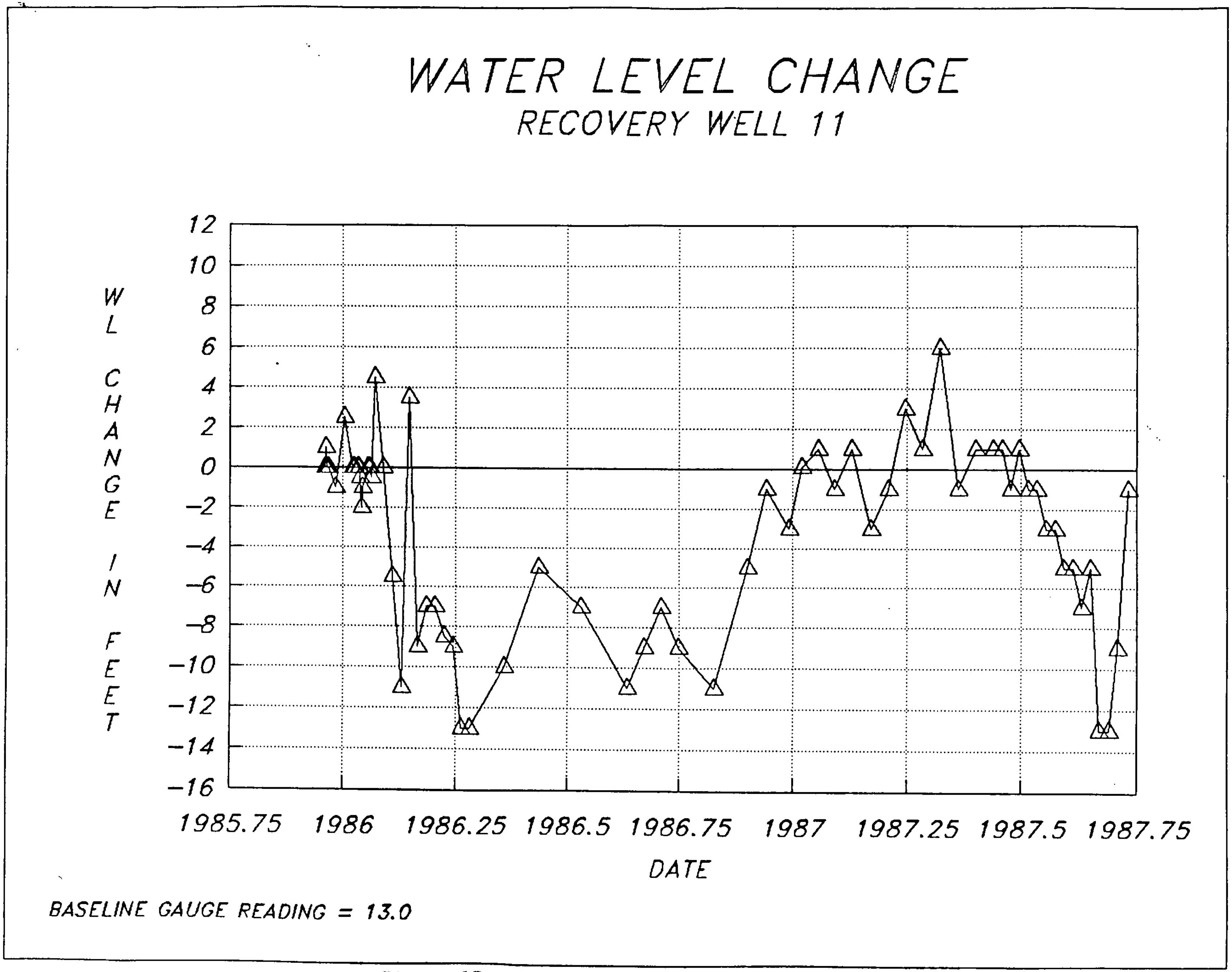

Figure 15. Water Level Change Recovery Well 11

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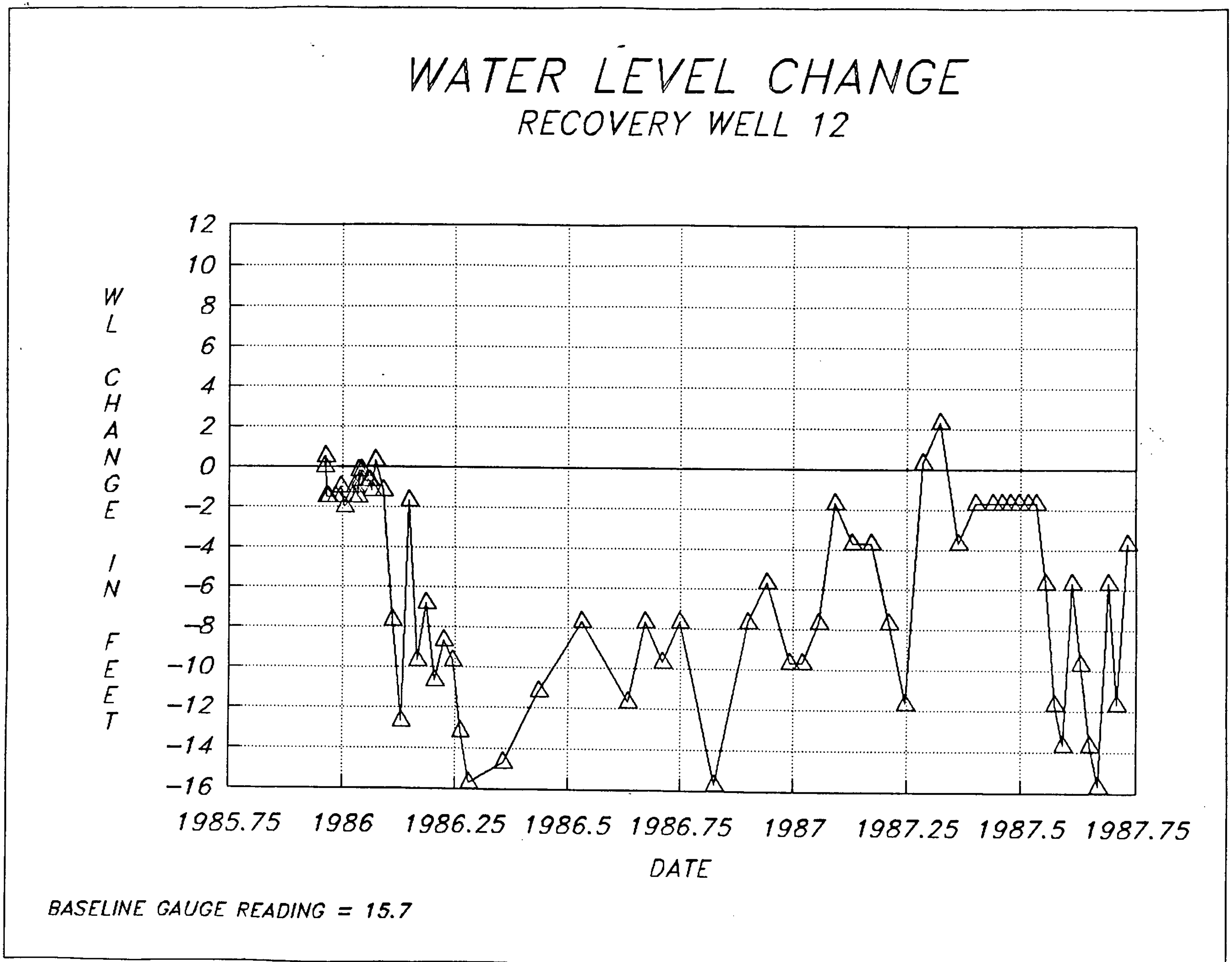

Figure 16. Water Level Change Recovery Well 12

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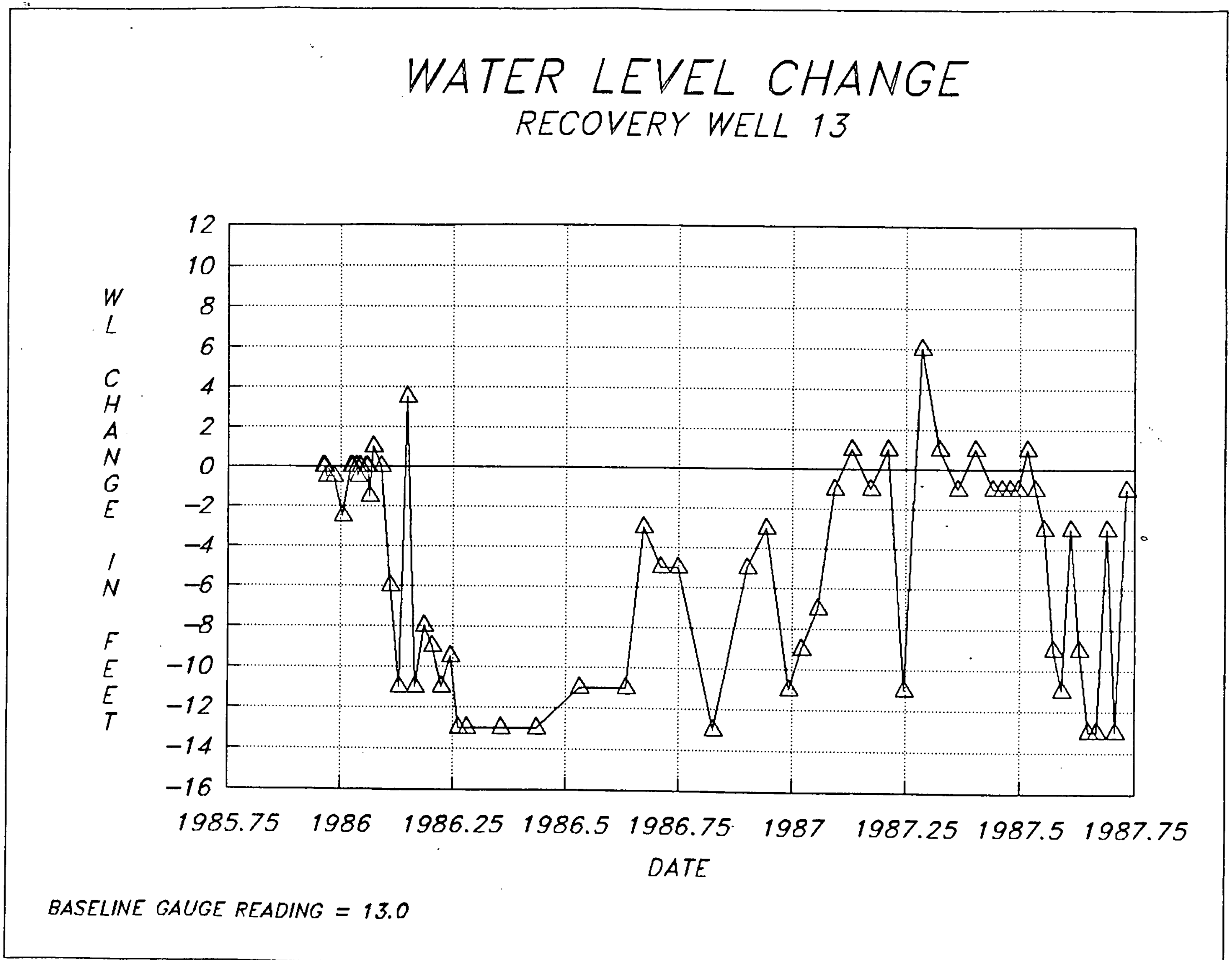

Figure 17. Water Level Change Recovery Well 13

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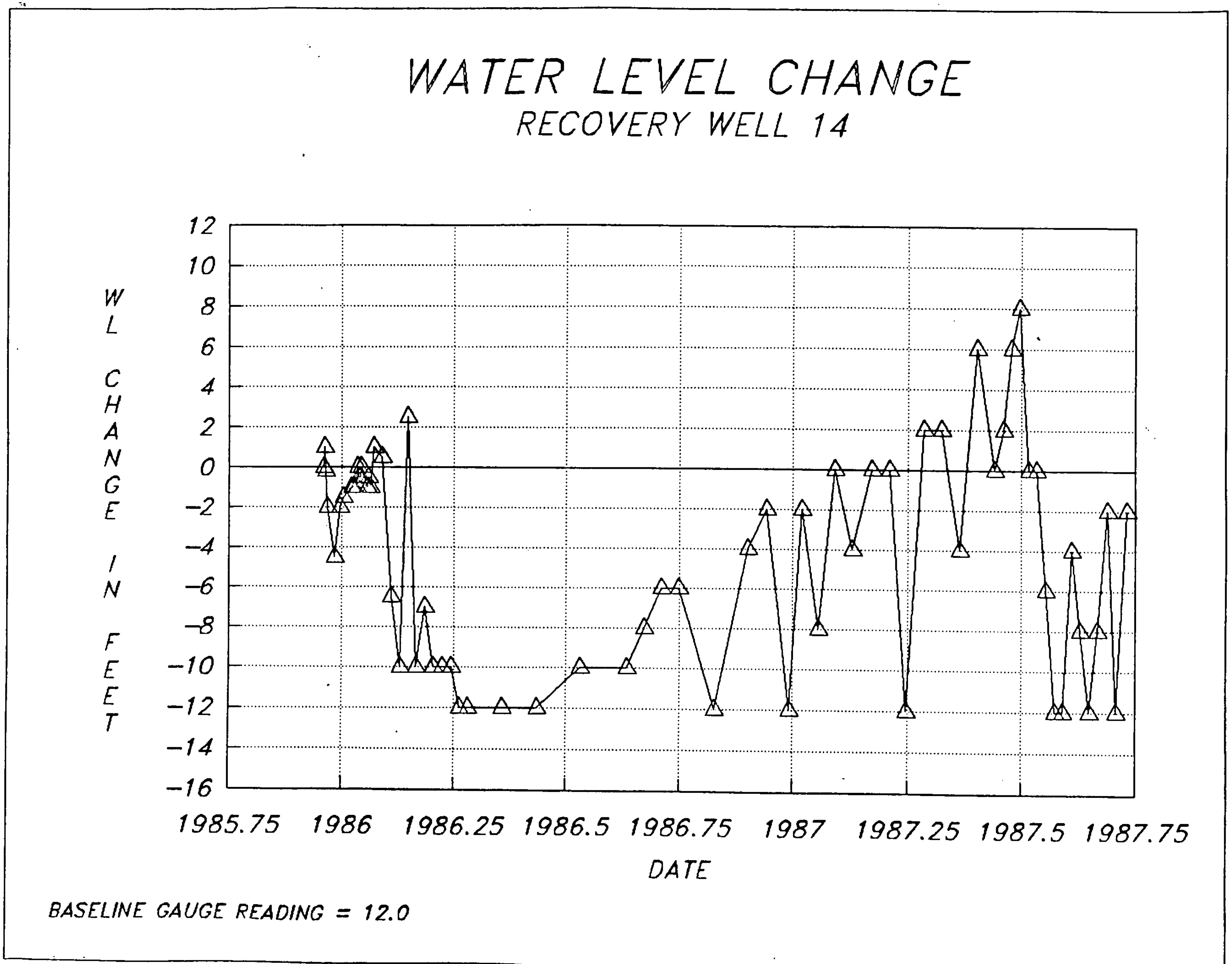

Figure 18. Water Level Change Recovery Well 14

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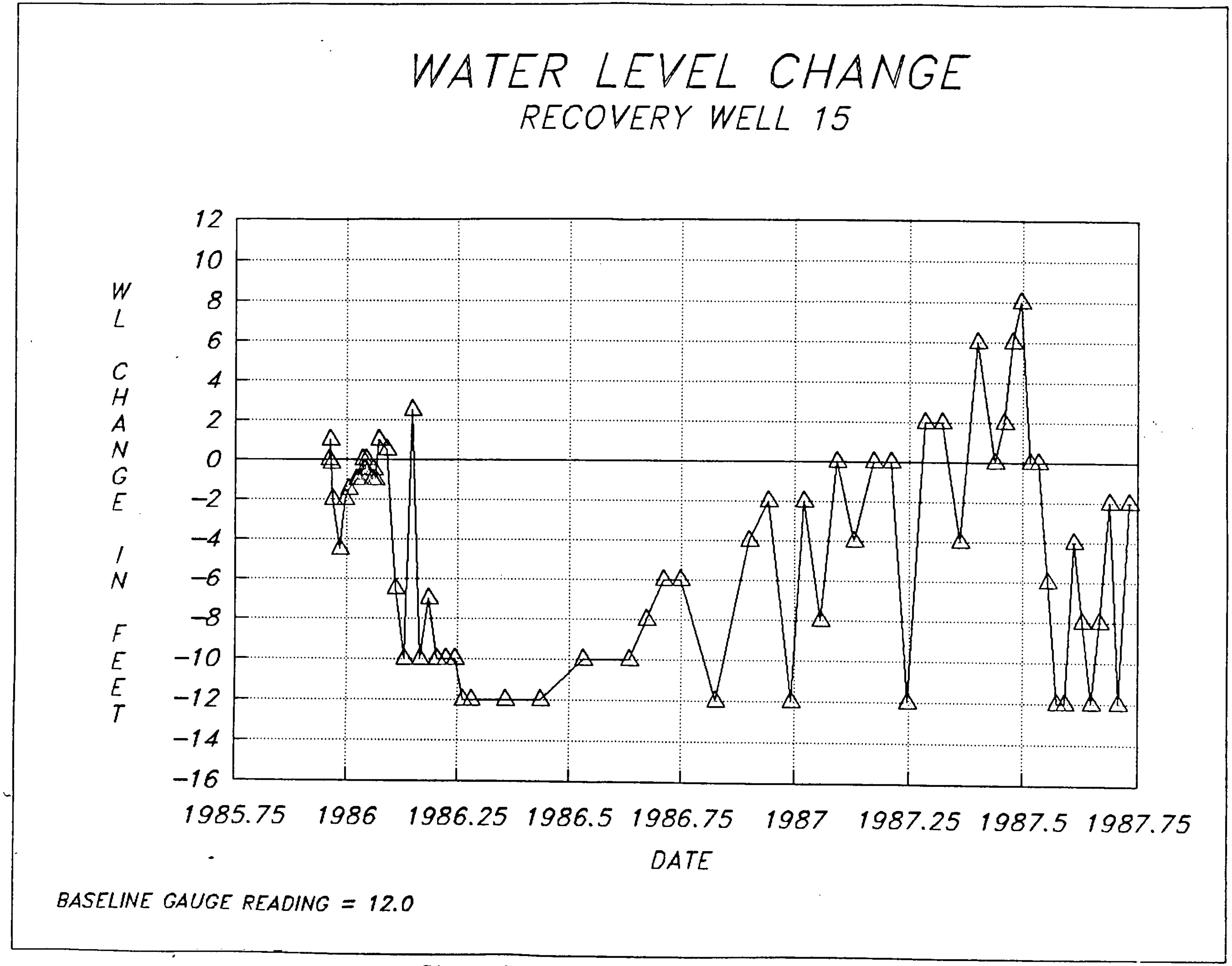

Figure 19. Water Level Change Recovery Well 15

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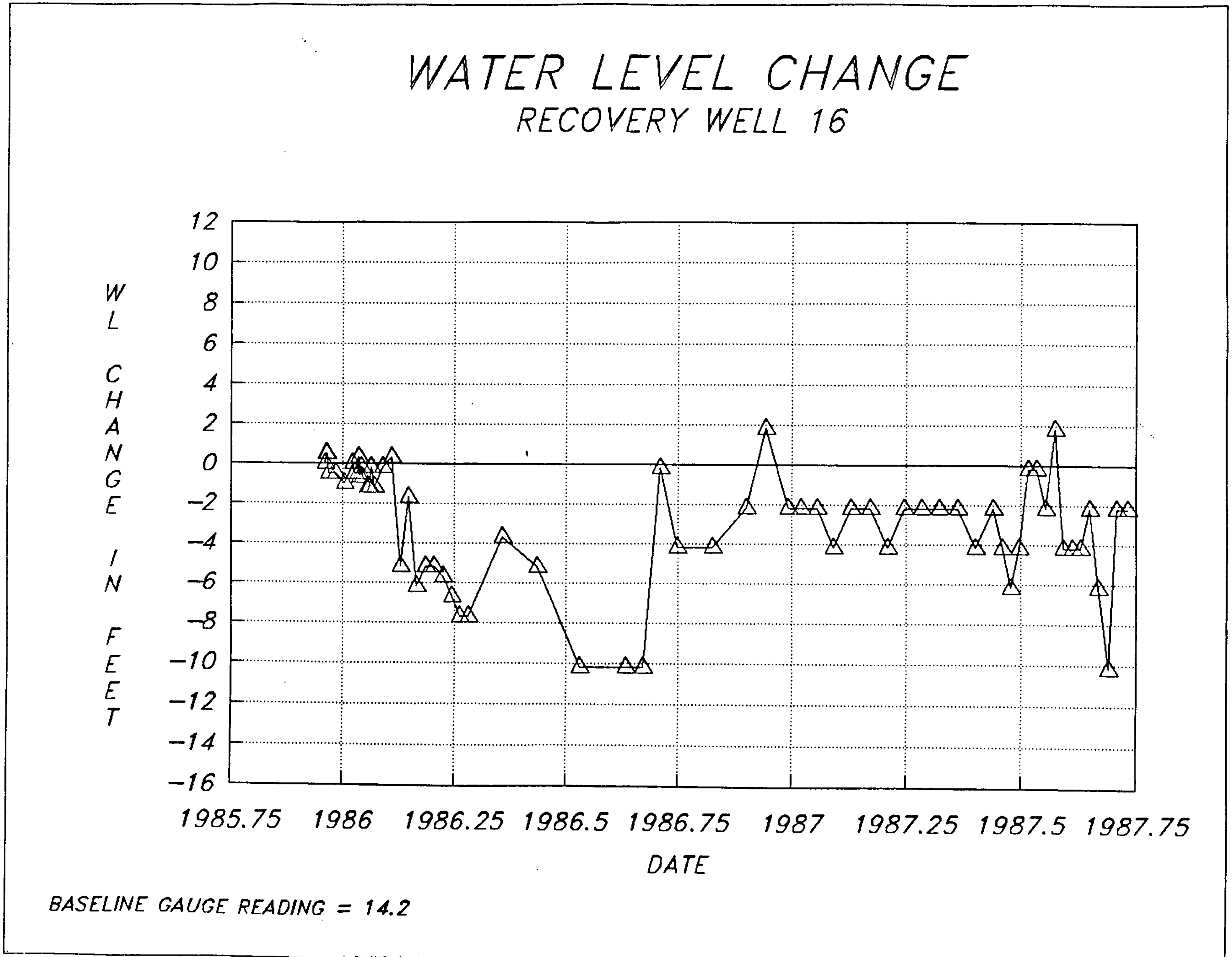

Figure 20. Water Level Change Recovery Well 16

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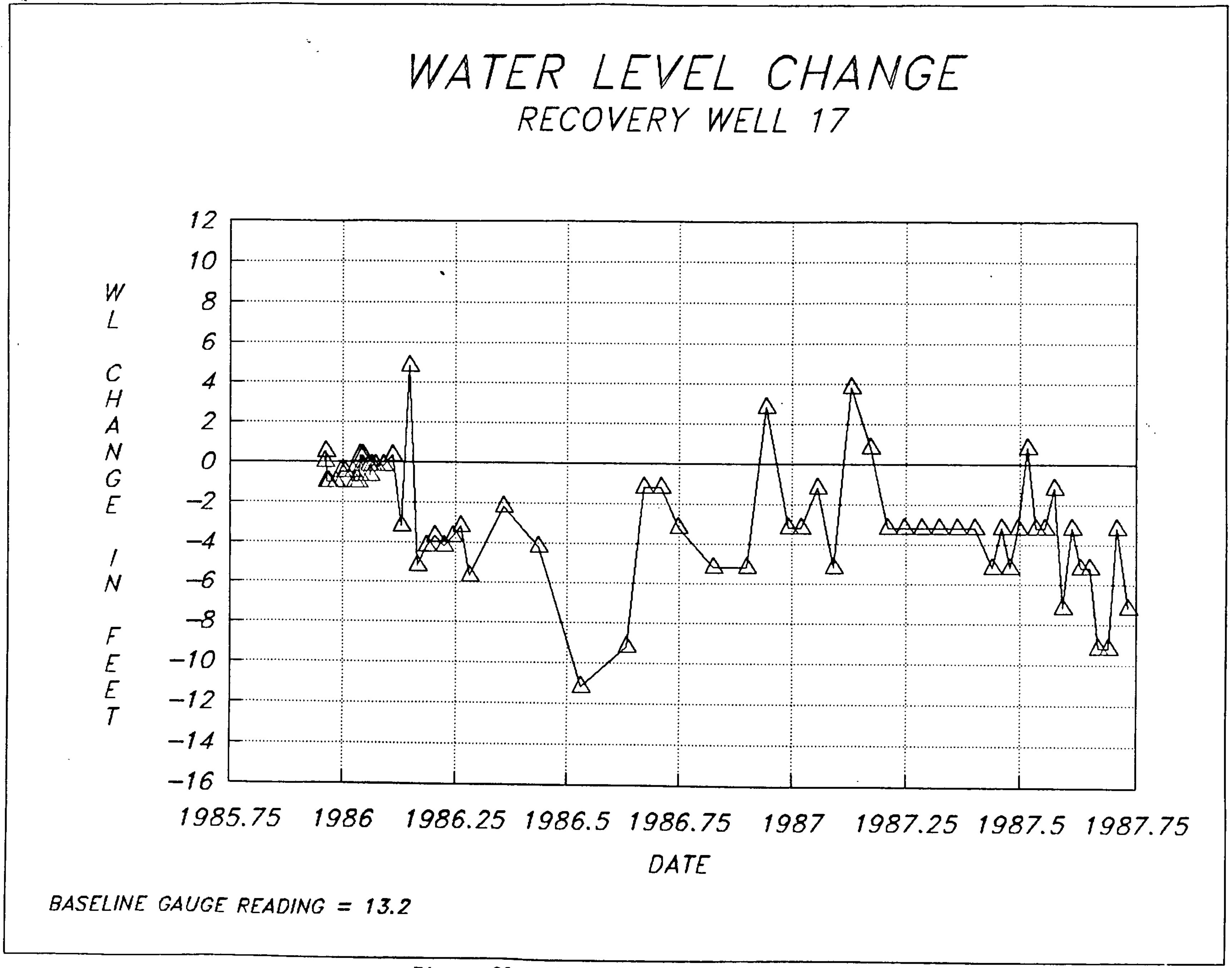

Figure 21. Water Level Change Recovery Well 17

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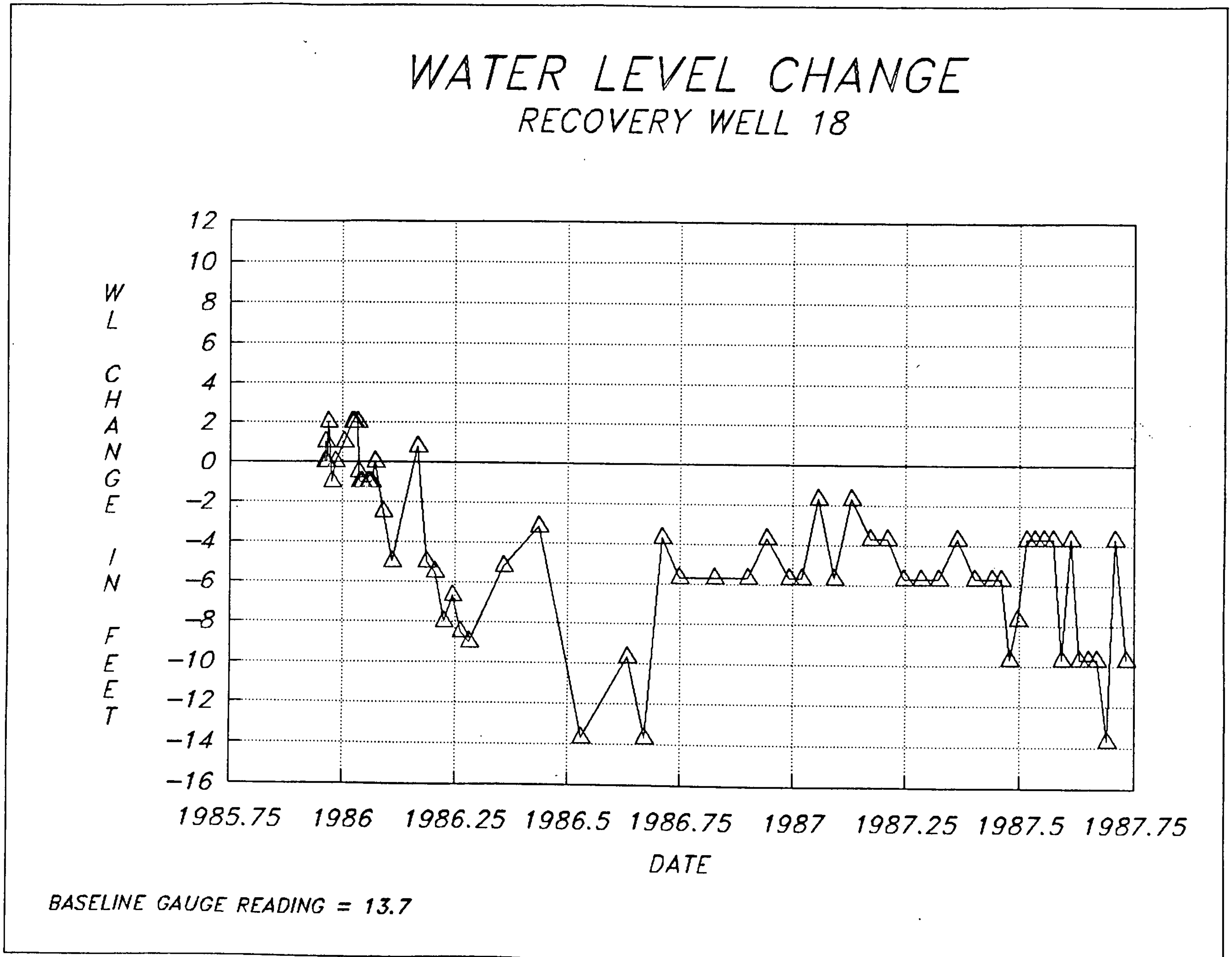

Figure 22. Water Level Change Recovery Well 18

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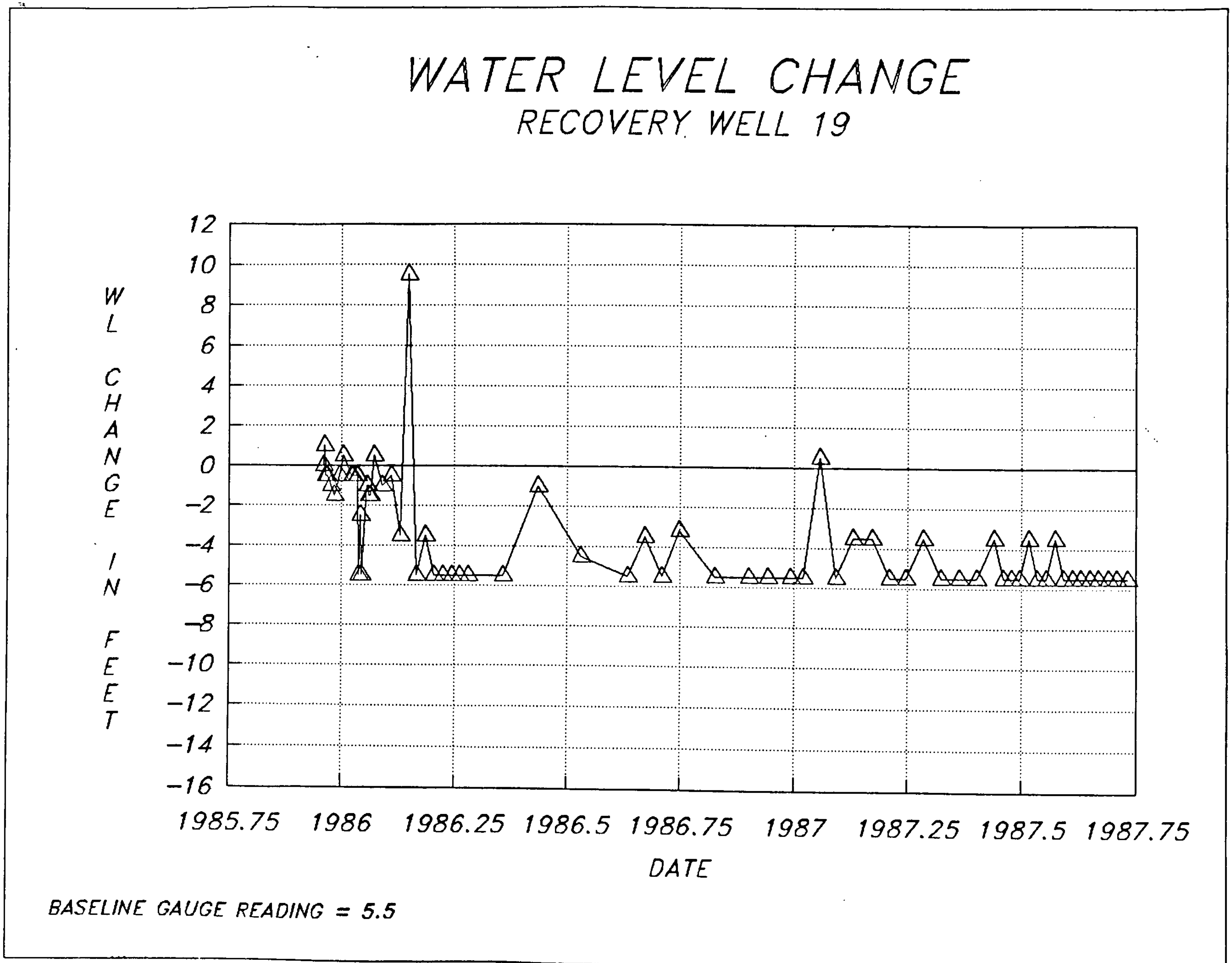

Figure 23. Water Level Change Recovery Well 19

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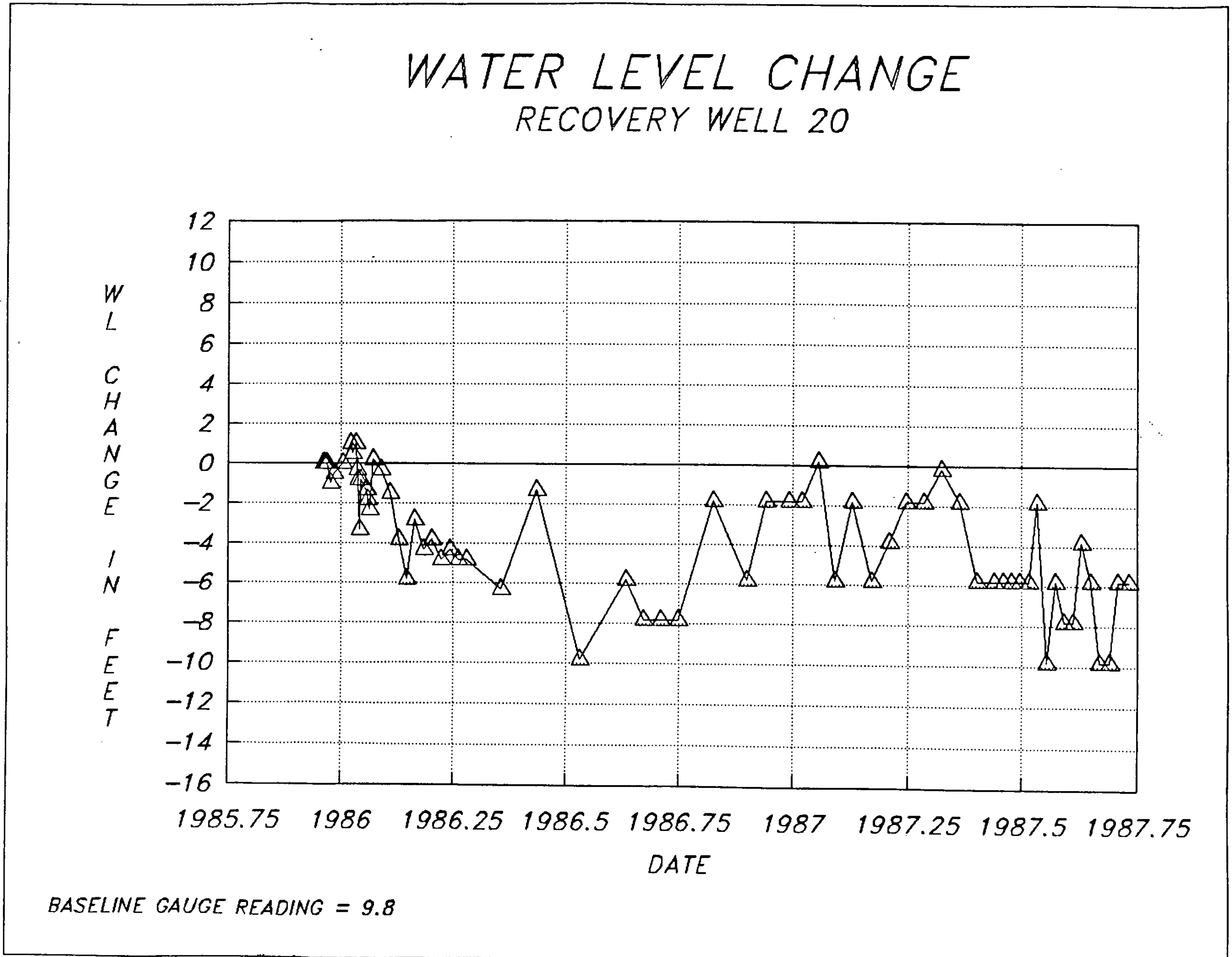

Figure 24. Water Level Change Recovery Well 20

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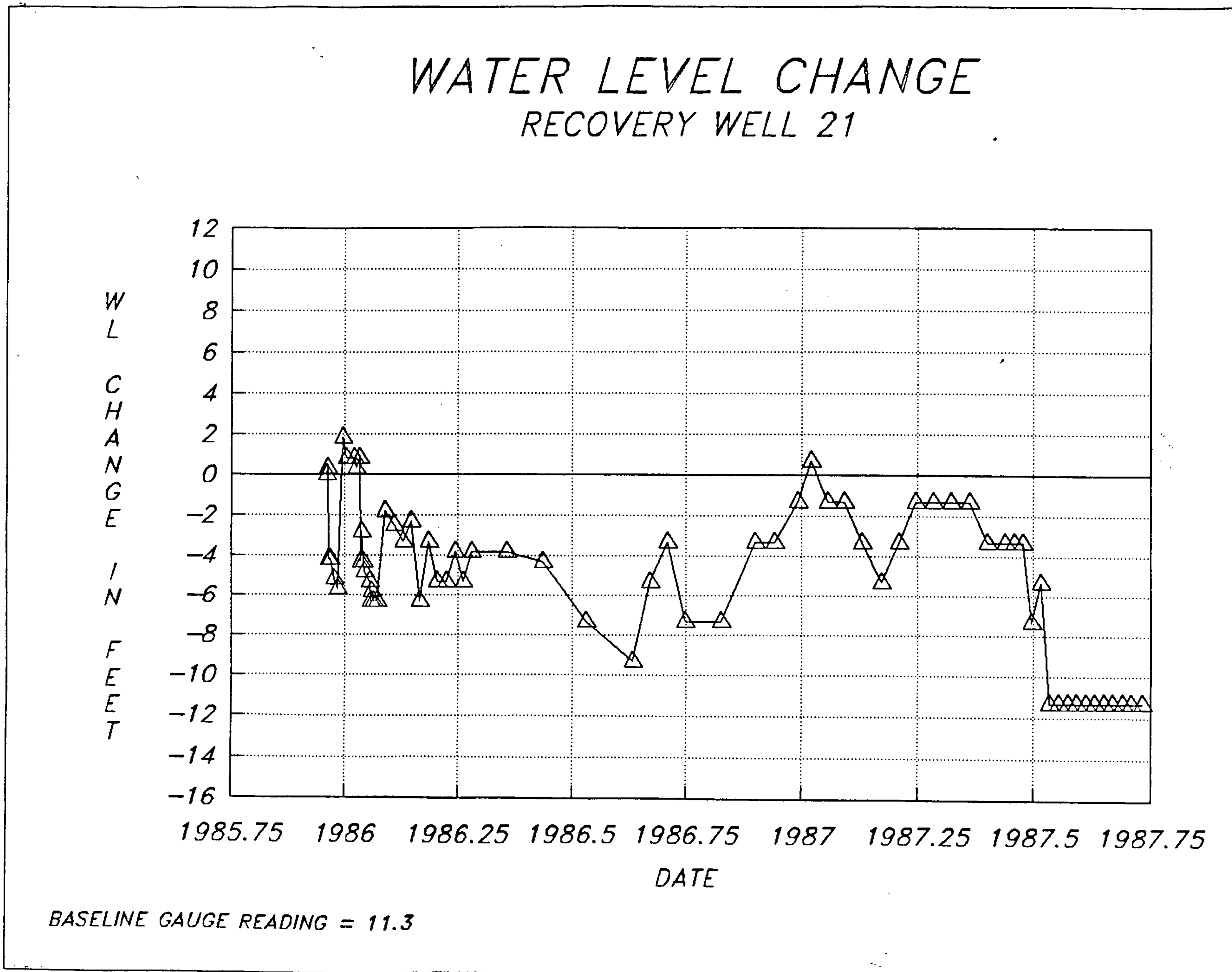

Figure 25. Water Level Change Recovery Well 21

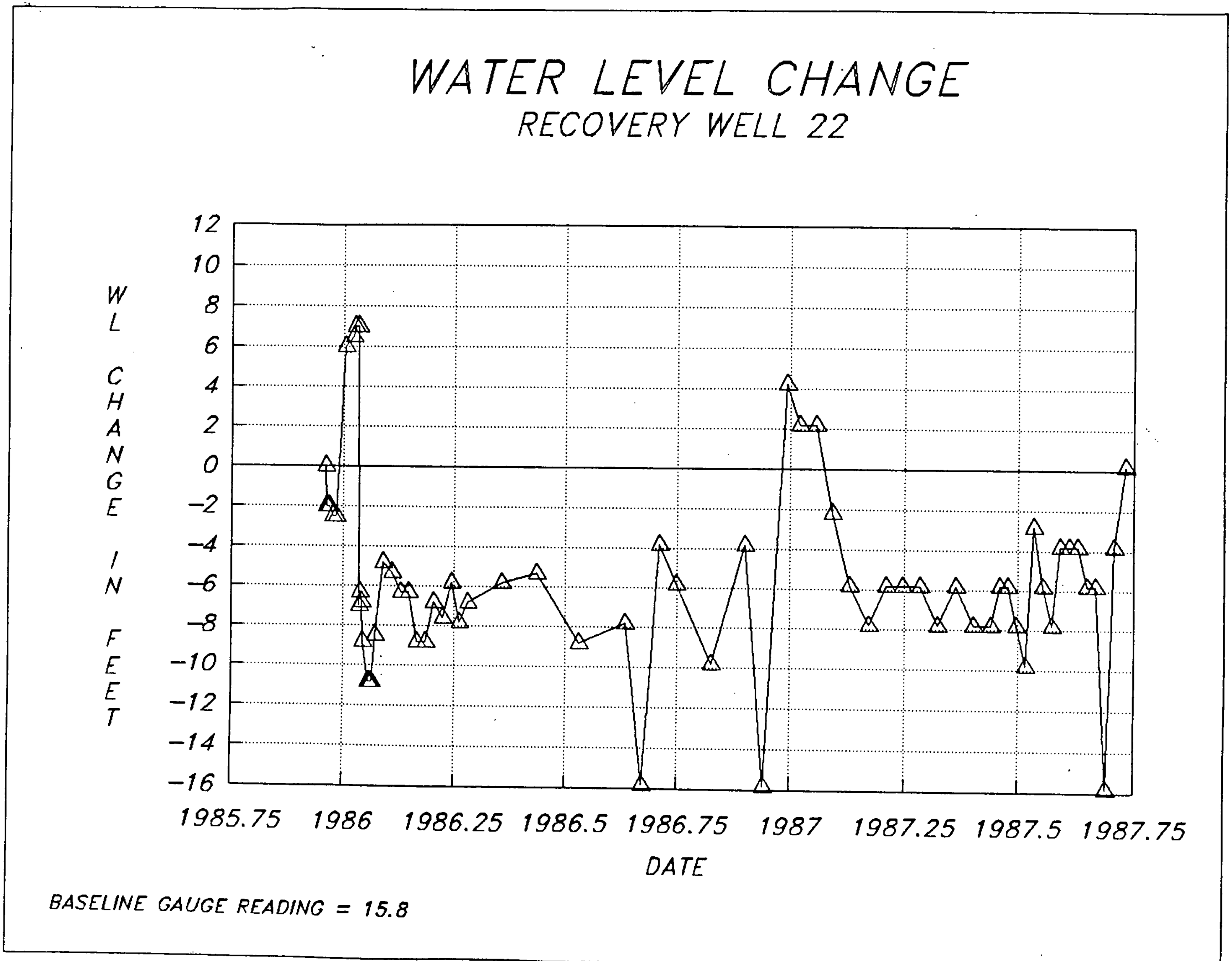

Figure 26. Water Level Change Recovery Well 22

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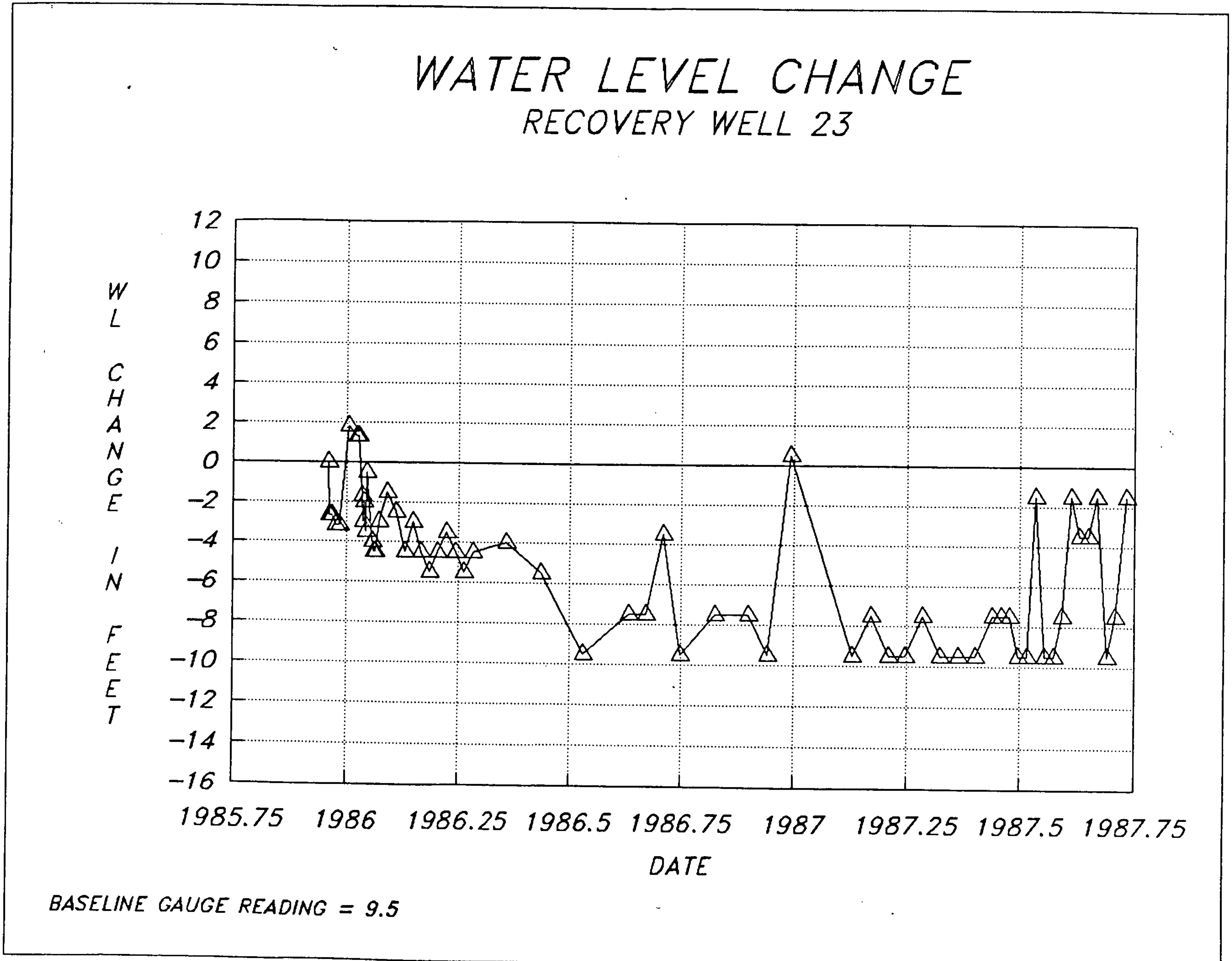

Figure 27. Water Level Change Recovery Well 23

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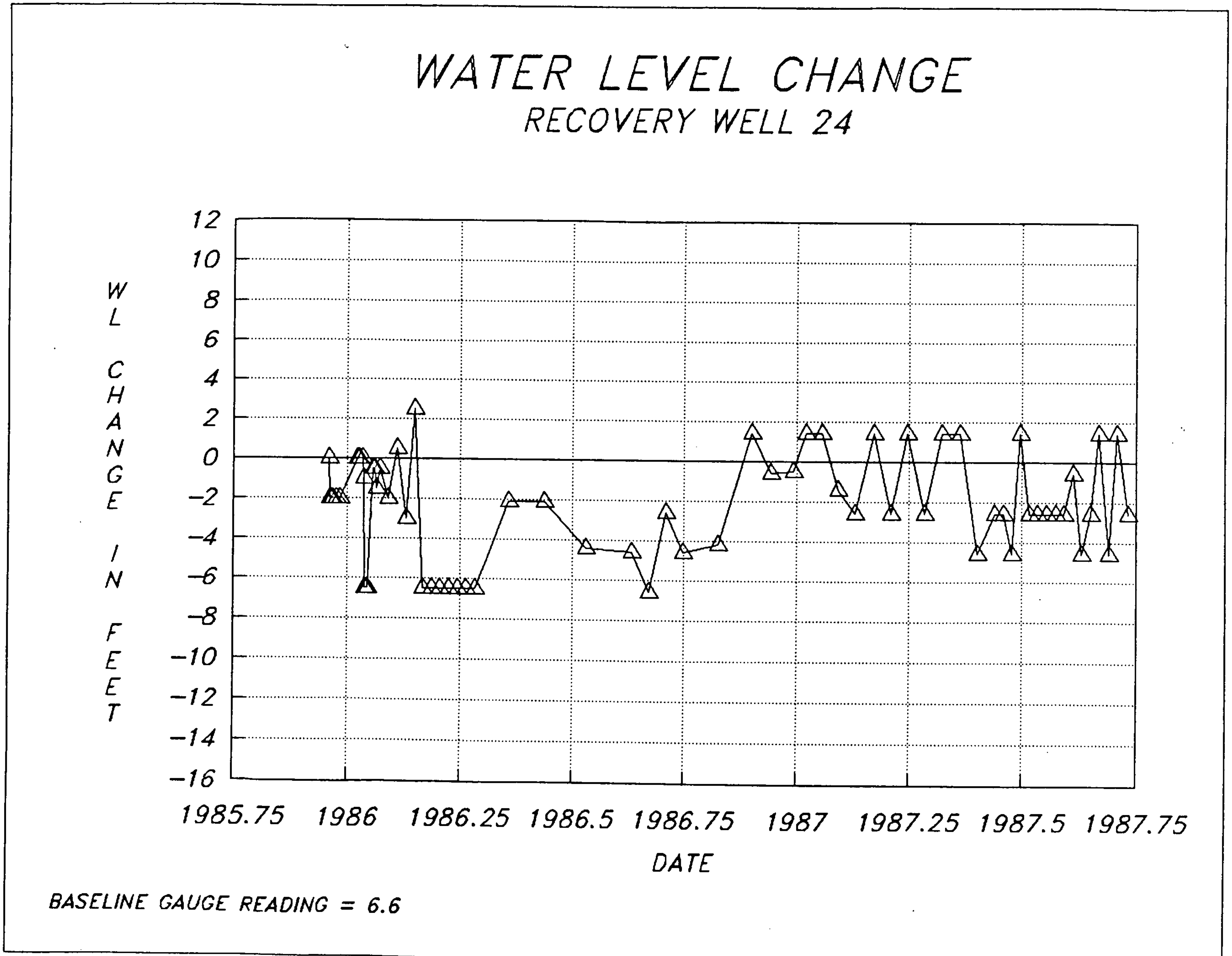

Figure 28. Water Level Change Recovery Well 24

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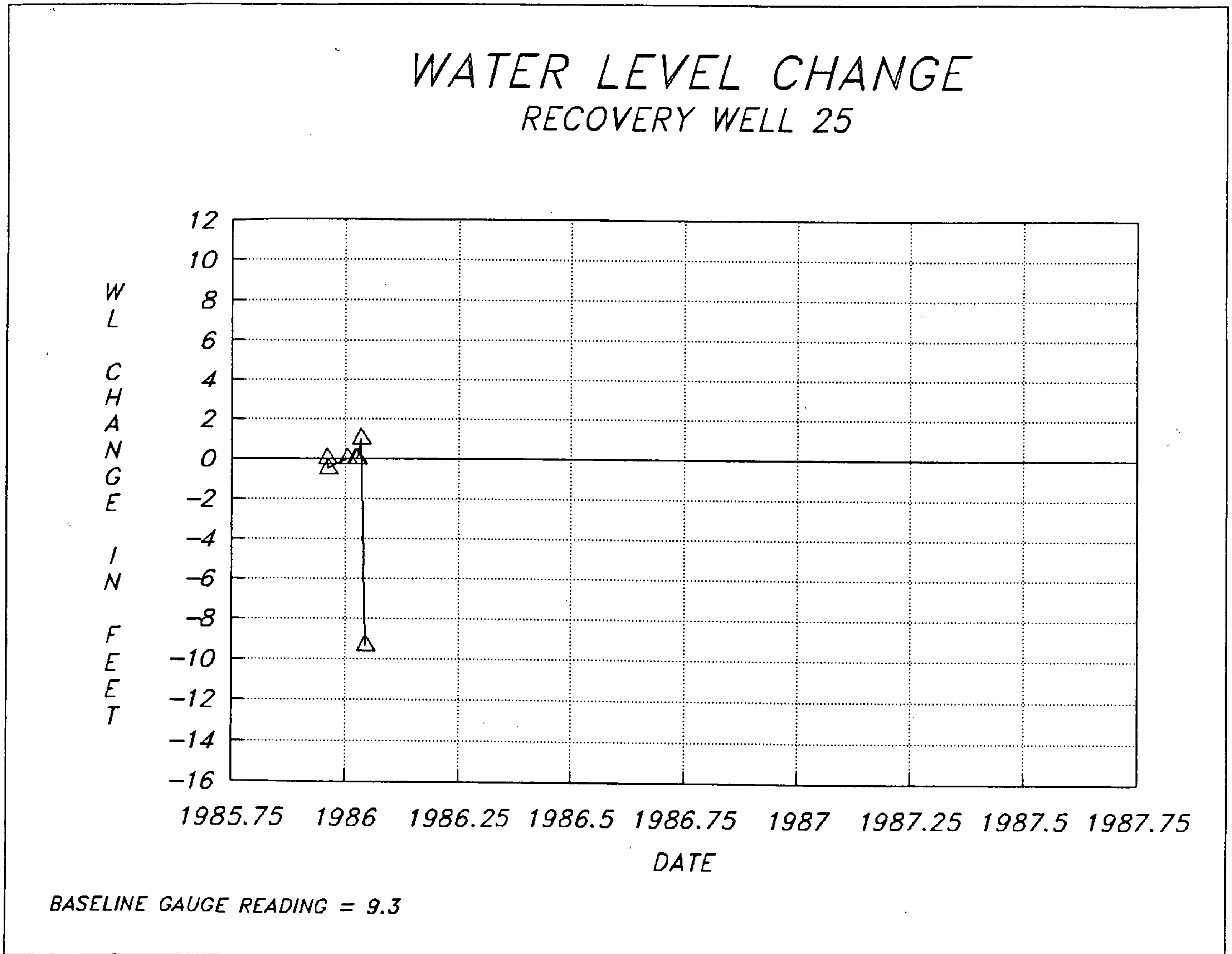

Figure 29. Water Level Change Recovery Well 25

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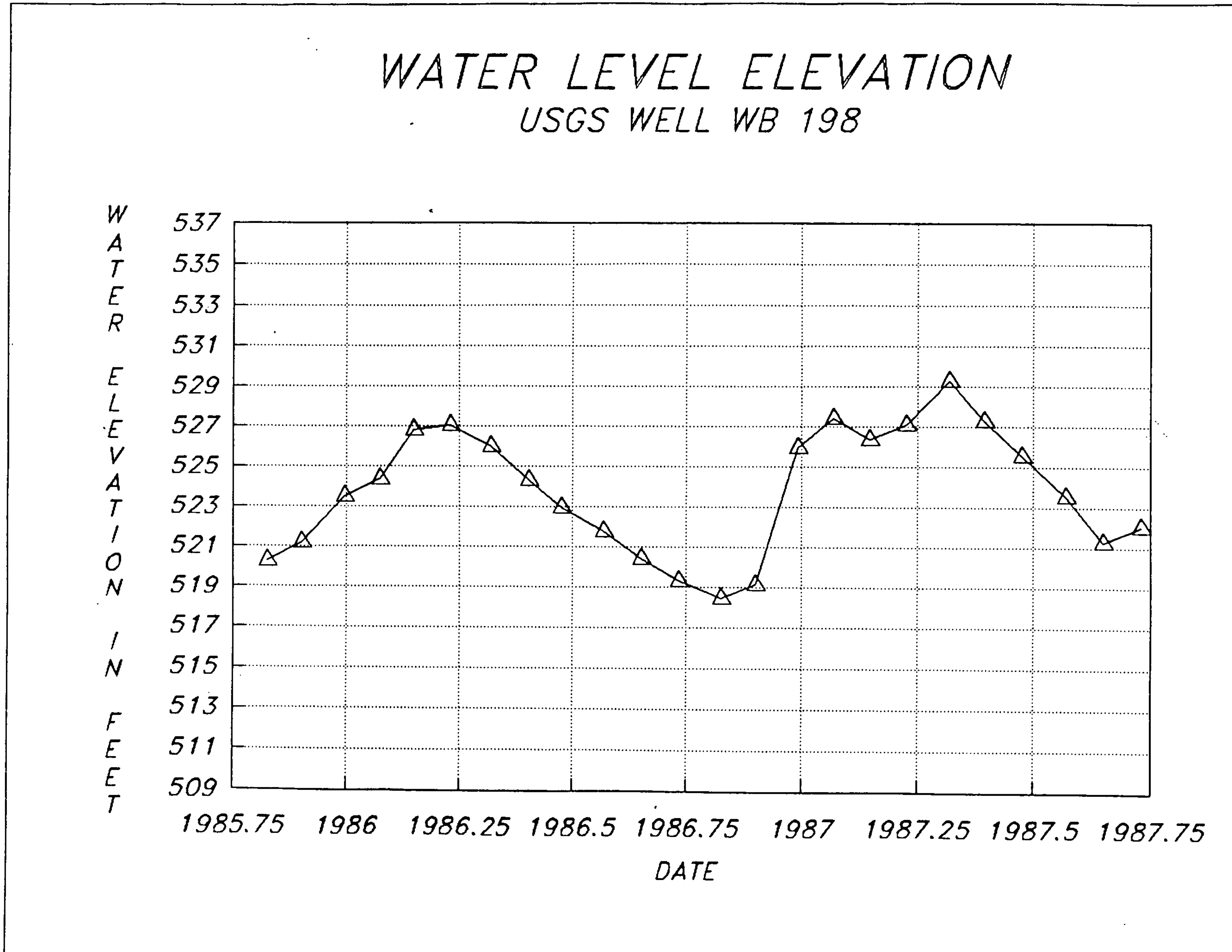

Figure 30. Water Level Elevation USGS Well WB 198

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